Compendium

by armada

Land Robots

From throwables to trucks

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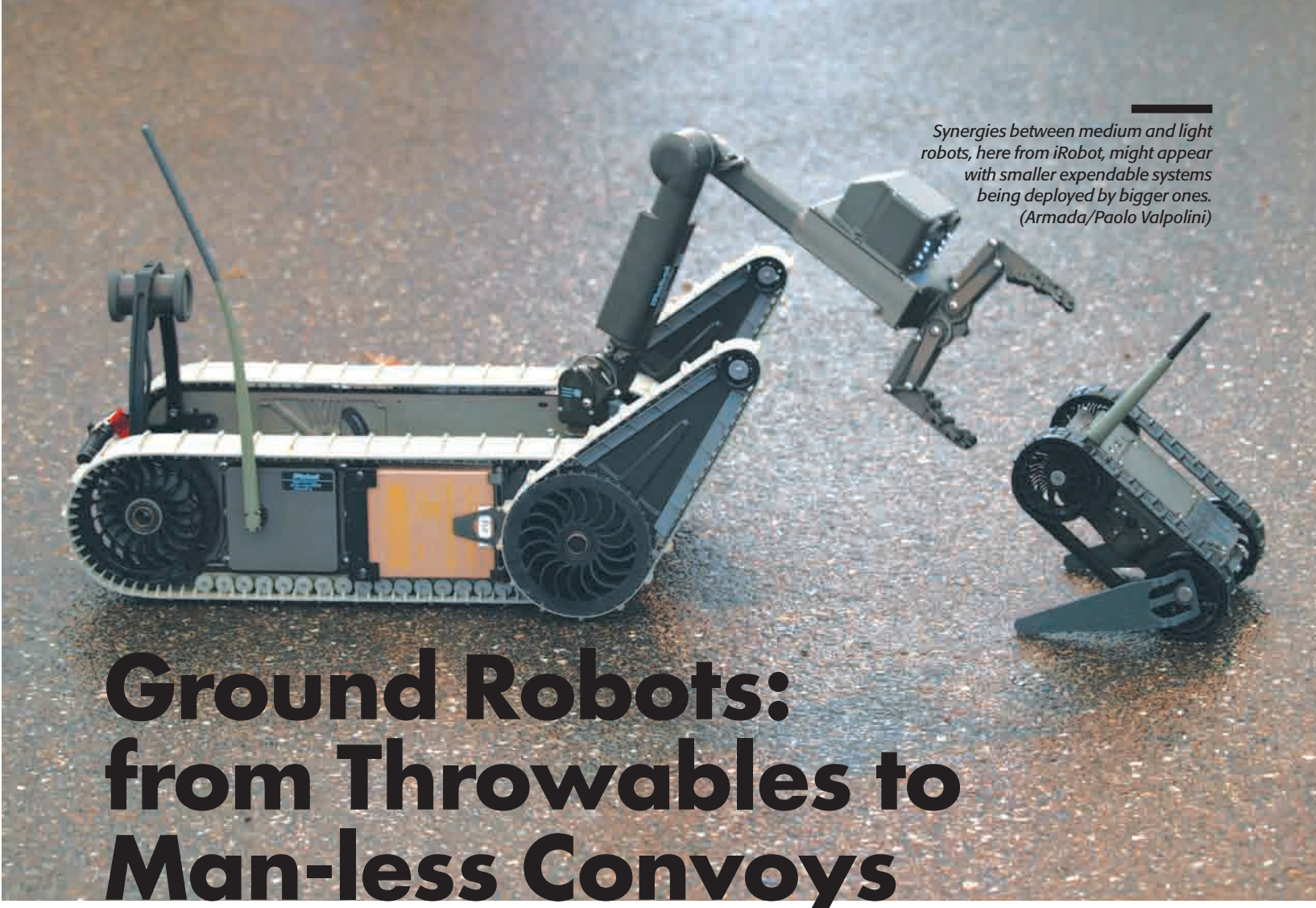


Synergies between medium and light robots, here from iRobot, might appear with smaller expendable systems being deployed by bigger ones. (Armada/Paolo Valpolini)

Ground Robots: from Throwables to Man-less Convoys

Amongst the three environmental elements that are represented by sea, sky and land, the latter is certainly the most difficult one for an uninhabited vehicle. While drones and surface or submersible naval unmanned systems mostly evolve in a consistent environment, ground robots have to deal with all sorts of obstacles. Not only do these complicate their displacement, but they also limit the range of their data links.

Paolo Valpolini, inputs from Eric H. Biass

In the kingdom of drones, the smaller the drone the most affected it is by wind gusts. Ground robots suffer from a similar scale syndrome, where physical dimensions have an impact on mobility, at least as far as the most classic mobility solutions are concerned, namely wheels and tracks since walkers and creepers are still far down the development road.

Most affected are the mini-ground robots. Their limited weight also affects the range of their datalinks, as well as their endurance, since they usually are powered by batteries.

It is always difficult to split systems into categories; however it is safe to say that up to five-kilos a first range can include what are called the mini-ground robots (let's keep the micro category aside for the future, should it ever appear). This has sub-categories, namely the throwable robots up to three kilos, as the heavier ones are more droppable than throwable.

Another form of co-operation between ground robots and drones is here exemplified by HDT Global Protector deploying a tethered drone to provide early warning to a convoy. (HDT Global)

Next up range is the medium category – a different world really, where payloads weights are measured in kilos rather than grams and provide much greater flexibility. Here the robots themselves weigh from five to 30 kilos.

For practical purposes, this Compendium only deals with robots that can be tactically employed on the battlefield by soldiers, as explosive ordnance disposal robots are considered specialists' systems developed to deal only with a very specific mission. The aim of this Compendium is to examine what is available to the standard soldier to increase his safety and flexibility on the field.

Obviously many multirole ground robots can be equipped with robotic arms, grippers, water cannon and so on, which effectively turns them into mobile bombs although this will be only one of their many roles.

"The aim of this Compendium is to examine what is available to the standard soldier to increase his safety and flexibility on the field."

Higher up, above the 100 kg mark, heavy robots can have a say on the battlefield in missions such as reconnaissance, resupply, casevac, etc. For example – one of many potential applications – Supacats are used In the British Army to bring ammunition supplies to the front line, exemplifying a situation in which the driver, who is highly exposed, could usefully be replaced by a robotic system.

Tiredness and loss of concentration was identified by the US Army as a main factor of accidents in logistic convoys, with roadside bombs only adding to that in terms of casualties. As a consequence a number of companies in America and Europe are developing systems that allow to quickly transform a conventional vehicle into an unmanned one. This can be applied also to engineers' equipment whereby, for example, a scraper can be turned into a man-less mine-clearing asset.

Modularity is here exemplified by Nexter's Nerva robots, with interfaces for chemical detectors, infrared cameras, CS grenades, audio intercom, disruptor, as well as a void module to adapting other sensors. (Armada/Paolo Valpolini)

The huge advantage of those systems is that they can be acquired in relatively small numbers and installed on the field into standard trucks or vehicles, and later shifted to other vehicles for different missions or when the vehicle in which they are installed suffers a major failure.

Compared to drones, ground robots definitely are a less mature breed. Not many embody an evolved form of autonomy, something that would considerably decrease the operators' workload while increasing the benefits of their use and making them a real force multiplier. A lot of arguments are brought against their weaponisation (drones suffer from the same problem) as their reliability is still considered insufficient (how much more reliable is the human being might also be questioned, especially in the light of blue-on-green incidents in some theatres of operation), legal advisors taking their toll on quick deployment of such armed ground robots. It is however clear that the operational era of ground robots has started, and that they will play an increasingly important role on future battlefields.

As these lines are being read, however, another factor is wrecking havoc on ground robots development: the financial crisis. In many countries, with America leading, numerous programmes have been slashed, affecting the development and acquisition of some of the systems covered by this Compendium. This, coupled to other events, has started a down- spiralling effect within the ground robotic community. Several well-known companies currently are wrestling with the financial problems resulting from order cancellations.

In America three programmes still appear to be alive: the Advanced Explosive Ordnance Disposal Robotic System, the squad-level Common Light Autonomous Robotic Kit intended as an intelligence sensor

Mini-ground robots – here an iRobot FirstLook – will essentially remain remotely controlled as increasing their autonomy would be too expensive, at least for the time being. One of the efforts to be made, however, is to improve man-machine interfaces to allow operators to maintain their tactical posture while guiding ground robots as illustrated by this Nexter Nerva controller. (Armada/Paolo Valpolini)

carrier, and the Engineer Squad Robot. The Squad Multi-Purpose Equipment Transport is another one of the programmes that should survive American defence budget cuts and sequestrations.

If they want to draw any attention from the American Department of Defense, all robotic systems (air, land and sea) will have to comply with the Joint Architecture for Unmanned Systems (JAUS) and respect the Interoperability Profile (IOP). Head-on control systems, reduced workload, semi-autonomous control, swarm capability seem to be the development trends.

What does the future for ground robots look like? How many of them will be around on the battlefield in 2020? Difficult to say. What is obvious is that the technological evolutions allied to the absolute need to reduce casualties among western contingents deployed downrange will inevitably spark off the necessity to thrust the man-less system capability forward in the ground operational community. Very few at the beginning of the century were convinced of usefulness of drones, yet they now make the headlines everyday – and many are now proposed for commercial applications. Will the same happen to ground robots? The answer is probably yes, if we consider that according to the "US Program Manager Robotic Systems Joint Program Office", ground robots allowed to save the life of over 800 soldiers in Iraq and Afghanistan combat missions.

French Army looks at ground robots

With the Phase 1 of the Scorpion programme confirmed by the French Minister of Defence in June 2014, the *Armée de Terre* is now looking into Phase 2, of which robotics is part and parcel. Robots within a tactical task force should be used in dismounted combat, with micro-ground robots (and their flying counterparts) to become the soldier's advanced eyes. Other robots of similar dimensions might fit into the equation delivering effects on the ground against the enemy, but also to the profit of the task force, improving communications by deploying radio relays for example.

The more sophisticated micro-robots might be tasked with reconnaissance for higher echelons taking part in mounted combat. Tactical multirole robots are being considered for reconnaissance by contact, resupply missions and as effectors while heavier robots might be used mostly for route clearance and engineer missions. The use of systems capable to transform standard vehicles into robots is also envisaged.

The Minis: the Infantry Squads' New Tools

Pending the advent of the nano-ground robots, short-range intelligence, surveillance and reconnaissance missions are mostly covered by light ground robots capable to move in restricted areas, with data links providing a limited operational range. Many of these belong to what we can define as the "throwable" category, as they can be launched to a certain distance and height by the operator, inside a building for example, without needing to be driven there.

The junior member of the iRobot family is the 110 FirstLook, here employed to assess the presence of an IED. (iRobot)

Often considered expendable, they can fit into one's pouch or pocket and feature small and light control stations, some now even being controllable by smartphones. Alongside the light throwables are slightly heavier robots that can be easily dropped from a vehicle (when not equipped with extra payloads), but that can hardly be launched through a first- floor window; they remain among the systems of choice for basic infantry units, as they do not dramatically increase a soldier's burden and compensate this by providing him with a new, easy to operate, capability.

THROWABLES

ReconRobotics: Formed in 2006 and based in Edina, Minnesota, ReconRobotics has been one of the fast-developing companies in the ground robotics field, and is about to reach the mark of 4,000 systems in use worldwide with an even split between military and law enforcement applications. American defence budget cuts strongly hit the company in 2014, following the US Army's decision not to acquire over one thousand robots in 2013. This led to heavy layoffs in early 2014, although a company official recently told Armada that the strong

The Throwbot XT is one of ReconRobotics two best-sellers with the bigger Reconscout XL. (ReconRobotics)

international and law enforcement market will help compensate the loss of American military orders. Currently 90% of the company sales is based on two models, the Throwbot XT and the Reconscout XL.

At only 540 grams – the average hand grenade weighs between 400 and 500 grams – the Throwbot XT is the lighter system of the family and was introduced in mid-2012. The comparison with a grenade goes even further as to activate the robot the operator must pull the activation pin from the robot to power it on. Its lightweight and its tubular structure, which provides a good handgrip, allow to throw it at distance, the company mentioning a 36-metre maximum distance, dictated by the robot impact resistance which also allows to drop it from nine metres height. The tubular structure hosts two brushless electric motors that ensure the propulsion of the two side wheels, while the rear tail ensures balance and orientation. Each wheel has eight flappy paddles that ensure maximum mobility over obstacles, the overall diameter being 114 mm. The tubular body also hosts the battery, that provides a one hour endurance on flat terrain, as well as sensors.

The main sensor is a low-light sensitivity black-and-white camera operating at 30 frames per second, equipped with an optic providing a 60° field of view; when light goes under the established threshold the infrared illumination source is automatically activated, ensuring view to over 7.5 metres. A high-sensitivity omni-directional microphone allows the operator to listen to noises or conversations. The acoustic signature of the Throwbot XT is very low, ReconRobotics declaring a noise of 22 dB at a six-metre range, which is that of human breathing at 0.2 metres; to deploy the robot silently in a lower position a small hook is available at the tail extremity to clip a cord, while for delivering it in a high position ReconRobotics developed the SearchStick. This is a 1.83-metre long telescopic aluminium pole with a button-activated clamp (only 0.52 metres long in stowed position); it can also be used to recover the robot at the end of the mission, or to use it as a pole-camera. The Throwbot XT datalink can be set on three different frequencies, thus allowing a single operator to control three robots. Speed is limited to 1.6 km/h, which is fully sufficient for a system designed to mostly operate in buildings or urban terrain. In those conditions the range is of 30 metres, which trebles in outdoor conditions.

Vivid illustration of what a Throwbot XT can be used for: smash through a window on a first floor and see what's happening up there. (ReconRobotics)

The ReconScout IR is a direct evolution of the previous robot, fitted with a black-and-white infrared CCD sensor with a 60° field of view, and an IR lighting system efficient at over seven metres.

The ReconScout XL, for its part, has a maximum speed of 2.16 km/h, which is higher than the Throwbot, but its resistance is lesser as it can withstand a drop shock from 4.6 metres and a throw shock of 9.1 metres. Its wheels have six spikes and a diameter of 140 mm, this robot being slightly noisier than the smaller one, operating at 32 dB at six metres. Sensors and data link remain similar.

ReconRobotic systems are controlled via the Operator Control Unit II (OCU II) that allows the operator to see the images captured by the robot sensor on a 3.5-inch display, sound being listened via a headphone. The OCU II weighs 730 grams and is equipped with a thumb-controlled joystick that allows to easily control the robot's movement. Two antennas have to be raised before operating the OCU II, six frequencies being available, the system height with antennas up being 510 mm.

While historically ReconRobotics' main market has been represented by the United States with thousands of systems sold, its robots are also in use in several other countries; in Europe its throwables operate in Denmark, France, Italy, Norway, Switzerland and Britain, while in other areas they are used in Australia as well as by Egypt and Jordan in the Middle East. In 2013 ReconRobotics was accepted by PEO Soldier - Sensors and Lasers group in the Soldier Enhancement Program as a Squad-Level Sensor Kit. The evaluation process is due to be completed by 2015. As for technical developments, ReconRobotics is currently working on a digital version of its Throwbot XT; this will allow to add flexibility to the radio link side, something which is becoming a must on the international market.

Nexter: In 2012 Nexter of France revealed its interest in ground mini-robots by airing the prototype of its Nerva – a 4x4 throwable with a weight of four kilos. Following a further development and industrialisation process the original Nerva became the Nerva LG, the first of breed of light robots launched by the newly formed Nexter Robotics division. When not equipped with top-mounted payloads the Nerva LG is fully reversible – in other words it is ready to operate as soon as it is – literally – thrown into action. A rear-mounted handle eases carrying and throwing. It can be dropped from a height of

For its Nerva robots Nexter designed quick replaceable modules that allow immediate retasking of the system. (Armada/Paolo Valpolini)

three metres or thrown out to seven. The Nerva LG has two speed ranges: one from zero to four km/h, and the other from zero to 15 km/h; the former is the standard mode and allows precision driving and orientation, and when greater speed is required the operator pushes on a button on the joystick tip which shifts in the high speed cog. Standard wheels have a 150 mm diameter though special sand wheels can be installed with wider treads and transverse grips, but if push comes to shove a track kit is also available. As a courtesy to special forces an amphibious kit was developed adding buoyancy elements and paddle wheels.

Fully modular, it is based on the "one-click" concept to allow quick replacement of wheels and battery. The Nerva LG is equipped with standard sensors that provide a 360° view by virtue of four cameras (the front high-resolution unit equipped with a lighting system) while audio feedback to the operator is done by an omnidirectional microphone. Picatinny rails or configurable plates ensure mechanical interface with payloads. Power comes in at 24V over 1A, while data are forwarded via Ethernet.

Nexter, however, has developed a Nerva interface to extend the one-click concept to payloads. Thus recce packages such as thermal cameras or directional microphones are available, as well as chemical detectors or mechanical devices to push or drag suspicious packages (an explosives disposal tool is under development). Its 2.4 GHz band link ensures an operating range of one kilometre in open

All Nexter Nerva robots have been designed to allow quick wheel replacement, in order to adapt the robot to the surface on which it will operate. (Armada/Paolo Valpolini)

terrain and 300 metres in urban areas. With an endurance of two hours, the Nerva LG can be controlled with different systems from ruggedised PCs to tablets and smartphones, in the latter case a 100 mW wi-fi link with a much shorter operating range replaces the standard one. Usually used as a remotely controlled system, the Nerva LG can however

The Nerva S is the lighter member of the Nexter robot family; the rear extendable handle used to throw the robot doubles as main switch. (Armada/Paolo Valpolini)

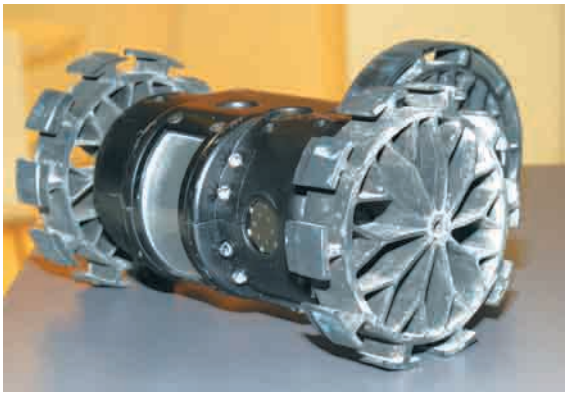
Novatiq PocketBot is a three-wheel robot that is marketed both for law enforcement and military use. (Novatiq)

also be fitted with semi-autonomous capabilities such as waypoint planning, automatic home return or follow-me functions. Numerous customers have ordered a few units each for operational testing. Nexter is expecting more substantial orders, following requirements for new payloads being filed from current customers.

The production model of the Nerva LG was shown at Milipol 2013, together with its smaller brother, the Nerva S. This is a two-wheel robot weighing only two kilos that can be used both indoors and outdoors, powered by a 2,700 mAh at 21.6 V Li-ion battery yielding an endurance of four hours. Powering up is effected by extending the rear tail, which in transport configuration is folded against the robot body to save space. The tail is used not only to stabilise the robot in operation, but also to throw it at long distances even from a moving vehicle as indeed the Nerva S has been truly designed as a throwable, its weight and hardness allowing it to break through a window. As with the LG, wheel replacement is a one-click job. To improve its mobility a wheeled strut can be added to each side to install tracks with the front wheels acting as the driving sprockets. This effectively turns the robot into the Nerva DS. The Nerva S has the same speed range as the LG and uses the same data link. It is equipped with a high-definition camera and a microphone, and visible and front-mounted infrared diode lighting round up the standard sensor description. The Nerva S can also be deployed with additional payloads that can be mechanically fixed on Picatinny rails. The Nerva S is in production.

Novatiq: This Swiss company produces one throwable type, the PocketBot, powered by three motors all contained within the vehicle's body, with one of them activating the third rear wheel through a belt transmission. Tipping the scales at only 850 grams, the PocketBot can withstand a drop shock of eight metres and a throw shock of 30 metres, and according to the company the three-wheel configuration allows it to considerably reduce its kinetic energy on impact compared to a four-wheel configuration. Once landed, and as soon as it moves the PocketBot recovers its normal stance, as it is not a fully symmetrical system. The two main wheels are equipped with T-spikes that ensure a smooth ride over smooth ground while providing optimal grip on sand, rubble and vegetation. The third rear wheel is smooth as tests showed that T-spikes caused an excessive grip that considerably slowed it in turns.

According to the company the 14 mm ground clearance PocketBot can deal with 30 mm vertical obstacles and climb 40° slopes. Up front the body a compartment houses a high-definition colour camera that can tilt ±90°. At low light levels the camera, which is equipped with a x8 digital zoom, switches automatically to monochrome low-light mode. An automatic infrared light is also available; however the operator can switch it to manual mode to use its white light. It also carries a waterproof microphone as well as a small waterproof loudspeaker allowing the operator to address people close to the PocketBot, hostages for example. Fixing points are available on top of the PocketBot for the installation of extra payloads such as a thermal camera or chemical sensors. Payloads must be factory installed though, in which case the PocketBot's throwable ability is sacrificed. The vehicle is activated through a



The PocketBot's two main wheels have been purposely designed to ensure maximum grip over different surfaces. (Armada/Paolo Valpolini)

Designed to cope with difficult terrain, hence the tracked solution, the StoneMarten can be equipped with additional payloads installed on the Picatinny rails seen here. (Novatiq)

top-mounted switch but it cannot be used by third party to disable it as this can only be done through the control unit.

In terms of control units, Novatiq developed the Crab-3. This 0.7 kg, 200 x 110 x 450 mm unit sports a 3.5-inch colour touch-screen and is powered by a one-click swappable replaceable battery – the same type used by the robot to reduce the logistic footprint, giving an operating time of four to five hours. A digital video-recording system saves the images on an SD card for further analysis. The PocketBot kit consists of one robot and one control unit, two chargers, four batteries, one headset, some spares such as wheels, antennae, caps, etc. The PocketBot is now a frozen base platform that is proposed to customers with a standard data link that ensures a 250-metre operational range in open terrain and 70 metres in non-line of sight situations. Novatiq is ready to replace the data link according to customer's will – a Coded Orthogonal Frequency Division Multiplexing (COFDM) system for example. Novatiq has already chalked up a number of orders in Europe and is about to deliver to an undisclosed Middle Eastern country, for special forces use.

The second ground robot in the Novatiq catalogue is quite heavier and tracked. Known as the StoneMarten it was designed to deploy sensors in high-risk areas on a wide range of terrain, hence the tracks to minimise dimensions and weight while maximising performances. Already sold to undisclosed European and African customers, it weighs 4.5 kilos, which puts it at the very higher limit of the throwables with an allowable drop shock of three meters and a throw shock of five. With two electric motors it can reach a maximum speed of seven km/h, and flippers give it a stair climbing capacity. This model features a front tilting high-definition colour camera, panning being effected by slowly shifting the robot in azimuth. Three more fixed colour cameras are available at the rear and on sides, all flanked by white and infrared diode lighting, while a microphone and a loudspeaker complete the standard suite. Picatinny rails provide grip for extra payloads, four plug-in ports being available for power, data and video signals. The robot has some degree of autonomy, such as return to last point of good communications or return to operator. Like the PocketBot, the StoneMarten is now a frozen platform, the company maintaining some flexibility by complying with customers' needs.

A new series of vehicles is being developed by Novatiq – all named Nova with a suffix. Data provided herewith and in the table are provisional as these products are really at prototype stage. The smallest of the new breed, which is definitely part of the throwable category, is the NovaCTR, for Close Target Reconnaissance. Even lighter than the PocketBot, it is tracked and can be considered a complement to the three-wheeler. This 600-gram unit has the same impact resistance as the Throwbot. In terms of sensors, it features a fixed colour front camera with infrared or white diode lights as well as a microphone and a loudspeaker. Declared range is 100 metres in line of sight and 30 metres otherwise. The NovaCTR is a frozen design and has just been added to the Novatiq portfolio, the company being currently in discussion with some potential customers.

Slightly heavier but still fully part of the throwables come a couple of robots, the NovaMRR (Medium Range Reconnaissance) and the Nova SRR(Short Range Reconnaissance), respectively a wheeled 4x4 and a tracked chassis with flippers. However as option the two chassis can become respectively tracked and wheeled. The NovaMRR has a higher maximum speed compared to its tracked counterpart – 10 km/h versus 4.7 km/h – the latter being able to climb up stairs. As for throwing parameters, the wheeled chassis can sustain a drop shock of four metres and a throw shock of six, with values dropping to three and five metres for the tracked brethren. The MRR is fitted with a front high-definition colour camera with virtual pan-tilt zoom, and with three fixed colour cameras mounted laterally and on the rear to provide 360° coverage. The SRR also has a front camera but fitted with a

The NovaSSR is one of the latest products from Novatiq of Switzerland, but another two new robots are at final design stage. (Armada/Paolo Valpolini)

Optimess of Germany has developed the two-wheel iSnoop, which can be equipped with different types of tyres, amongst which one designed for stair climbing. (Armada/Paolo Valpolini)

motorised tilt system, and while both robots are equipped with microphone and speaker for two-way communications with their operators, the tracked robot adds white and infrared diodes lighting all four sides. Both robots can carry a 2.5 kg payload installed on a Picatinny rail, a secondary mechanical adaptation with plate being also possible, while power and data are provided through Fischer connector accessory ports.

Optimess: A new entry in this field is the iSnoop developed by Optimess of Germany. It is available with different sets of wheels to ensure optimum mobility depending on terrain (including stairs) and required speeds. Its wireless communication system ensures a 50-metre indoor range and 200 metres outdoors.

A high-resolution camera with pan function provides video footage while a microphone ensures acoustic intelligence. Besides the standard camera other payloads can be installed such as gas sensors. The two-hour endurance iSnoop is in the latest development phase and should be available during 2013.

Robo-team: A couple of years ago Robo-team of Israel unveiled a light throwable robot known as Iris, a sweet acronym for Individual Reconnaissance and Intelligence System. It weighed one kilo with its two AA batteries that ensured four to six hours of operation, and could be launched with a David's sling system. Since then the Iris has evolved into a pre-production product. Highly ruggedised, it was built in composite materials and designed following a "safe box" concept, which allowed it to withstand shocks generated when falling from 10 metres or landing after a 65-metre side drop flight, which probably made it the "longest range" throwable robot. It was equipped with a front day/night camera with a ±90° tilt mechanism, a near-infrared and visible laser pointer and a microphone and a secure 200-metre range data link. Thanks to its symmetric design it could fall on both sides and be ready to operate. Its dimensions of 175 x 205 x 95 mm allowed a soldier to carry the Iris in his side pocket. The robot adopted a peculiar architecture, as the front axle was much wider than the rear one. Wheels were made of composite Nylon and had six spikes each to increase grip over rough terrain.

A second development step maintained most of the above features, including architecture. The David's sling concept was however abandoned though the Iris maintained its throwability. Dimensions changed to 229 x 203 x 94 mm, weight grew to 1.3 kilos, but added a one-kilo payload capacity. The wheels were also was modified. A number of Iris in this configuration were delivered to customers that used them both for testing and operations, providing Robo-team with invaluable data to develop the industrialised version that was first delivered in June 2014. The asymmetrical architecture of the proof-of-concept was abandoned in favour of a more conventional rectangular shape. A Picatinny rail on the upper side accepts payloads that can be linked via an RS232, a video/audio or an Ethernet port, in which case throwing is no longer an option. Fitted with entirely new wheels, the Iris maintains the ability to climb stairs, and according to

The latest version of Robo-team Iris is fully symmetrical and is fitted with a Picatinny rail allowing to carry a one-kilo payload. (Robo-team)

Robo-team Iris robots are equipped with a datalink that allows to establish a self-healing mesh, extending the range of those systems when used in urban scenarios. (Robo-team)

Robo-team its performances are increased compared to the first models. It can overcome a 64 mm obstacle and climb a 45° slope (100% in vehicle parlance), and has a maximum speed of 4.8 km/h. The data link system has a self-healing mesh capability that extends the robot's range, especially in urban areas. The Iris is controlled by a Rocu-5, a unit that also has evolved alongside the robot to offer a five-inch sunlight-readable, NVG-compatible, resistive touch screen, instead of the earlier 4.3" touch screen. The one-thumb stick remains while the number of push-buttons has been increased to six, three on each side of the screen. Memory is considerably increased with internal GPS, accelerometers and digital compass thrown in, as well as a front and rear 5MB camera. But what is more important is that the weight has been reduced from 700 to 540 grams for an operating time of between three and six hours.

Mistral Security: In September 2013 the Mistral Group acquired Israeli ODF Optronics, and de facto entered the ground robot producers' community. Developed to complement the first throwable sensor designed by ODF, the EyeDrive is a 4x4 that can quickly be transformed into a tracked device by the addition of rubber tracks onto the existing wheels, causing a slight increase in dimensions to 350 x 320 x 165 mm.

The EyeDrive weighs 3.76 kg, is fitted with one 0.08 lux black & white or 0.19 lux colour camera per side. An additional camera with a laser pointer can be installed at the front right of the robot. This can be

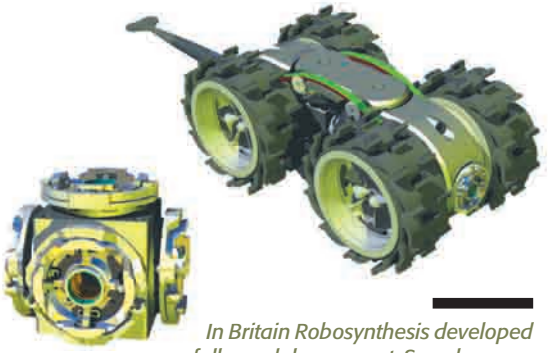
Following the acquisition of ODF Optronics by the Mistral Group, the latter is now promoting the EyeDrive. (Mistral Group)

oriented ±48° left or right, the view on the right being slightly reduced when tracks are installed. A microphone capable to pick up sounds at five metres is also part of the sensors suite. A one kilo communication unit, which can be connected via USB to a toughbook, ensures the link with the EyeDrive. The declared operational range is 400 metres in open space and 70 inside buildings, robots control signals being forwarded on a 915 MHz link while video signals are sent on 2.4 GHz. Lithium-ion

The addition of a handle allows an easier throw of the EyeDrive, or in this case its transport by a "K9" asset. (Mistral Group)

batteries provide an average endurance of two hours (time varies with sensors used, maximum payload weight being 3.5 kg). As usual Israeli companies do not announce export customers, but it is sure that the EyeDrive is in service with the Israeli Defence Forces.

Robosynthesis: Categorising ground robots is no easy task; with Robosynthesis this becomes even tougher as this British company has developed a fully modular system that allows one to reconfigure the size, configuration and role of its robots. Plug-and-play is the key word in the Robosynthesis system. Modules known as Robocubes are the key elements of the system, as not only do they have a specific role, they also have a processing capability, and thanks to a patented twist-lock universal socket manufactured in non-metallic materials, they ensure both the mechanical and the power and high data-rate connectivity. Mobility modules, sensor modules, power modules, CPU modules, lidar modules, communication modules, tool modules, are put together in a "Lego style" through the Universal Socket, the same system being used to install third party payloads. Currently the Universal Socket is being upgraded to an IP rating equivalent to submersion to 100 metres; this will enable Robosynthesis robots to operate in potentially explosive atmospheres.



In Britain Robosynthesis developed a fully modular concept. Seen here are drawings of the Armourdillo and of a Robocube element, on which most of the company robots are based. (Robosynthesis)

A design review to allow for implementation of modifications is underway to make the socket intrinsically safe and ATEX-certifiable. As for mobility, a number of different wheels have been developed to adapt the robot to any given terrain type. Robosynthesis drew inspiration from living creatures to optimise mobility: the "scram" hemispherical wheels for culvert inspections taking lessons from arthropods to use paddle-like gaits to avoid getting snagged on rocks or vegetation, while "claws" tyres imitate the leg action of insects and are being used for all-round all-terrain performance. Slave tracks, not usually in contact with the terrain, turn bottoming-out on obstacles into an advantage.

Using high-tech materials and technologies taken from Formula 1, such as metallised polymers, Robosynthesis robots are much lighter than those built with standard materials, which allows them to carry more payload or to have a much improved endurance with the same battery package.

Among the smaller robots proposed by Robosynthesis is the Armourdillo, a man-portable, throwable, tactical intelligence-gathering device that can be assembled in minutes without tools around the Robocube motor module. The robot provides 360° vision and its communications system has a mesh capacity to increase range and flexibility when using several Armourdillos. A rugged system, it can be launched using the removable rear tail; this is also used to increase stability and obstacle-climbing performance, "slave tracks" being also available for the latter role, and "claws" tyres for all-terrain capability. Four Universal Sockets, protected by removable covers, two on the upper side, one front and one rear, are available to add payloads up to two kilos, throwability being sacrificed when payloads are used.

Another Robosynthesis product that can fit into the "light" category is the Roboforce 1, a 2.9-kilo 4x4 with two connectors on top to allow two different payloads to be carried (a maximum of 2.5 kilos). One socket can be used to install a second power module to double endurance from 1.5 to three hours. An IP 67 item, it is submersible to one metre and is fitted with a Super OFDM data link that provides maximum throughput and an operating range of 1000 metres in open space and approximately 100 metres in urban non-line of sight environment. The Roboforce 1 is equipped with a front camera and has two speed ranges, 4.8 or 10 km/h. A range of daylight cameras or thermal imagers can be installed, as well as other types of sensors.

Armourdillo and Roboforce 1, both currently under development, are only two of the many ground robots that can be "assembled" using the Robosynthesis technology, an amphibious platform being among the designs currently under development.

Piap: This Polish company has developed the Taktyczny Robot Miotany (TRM), or tactical throwable robot. It has a cylindrical body that houses the electric motors and the electronics (including camera, diode lights and microphone). A rear stabilisation tail with a weight at its end ensures proper movement. Weighing 1.4 kilos, it can be thrown at 15-20 metres and can fall from nine. The TRM is 210 mm long, 167 mm wide and 190 mm high, it can reach a speed of over three km/h and has a one-hour operation time. Its control station allows to operate up to three robots, the transport case being designed to host three TRMs and one control station. According to information recently received by the author, Piap is further developing its TRM and a new version will soon be available.

MacroUSA: Not only land soldiers need robots; every year US Navy and Marine Corps personnel conduct thousands of Maritime Interdiction Operations (MIO) with their Visit, Board, Search, and Seizure (VBSS) teams performing search operations that often take place in hostile environments. Thus in 2011, the Space and Naval Warfare Systems

Developed from the Beetle, the MacroUSA Stingray is purposely designed to answer Spawar requirements for a robot to be used in maritime interdiction operations. (MacroUSA)

The latest versions of the 1.8-kilo dry weight Beetle could survive a three-metre drop on concrete and can carry a 700 gram payload. (MacroUSA)

Center Pacific conducted user evaluations on a number of small throwable robots and sensors to verify the requirements and develop the key performance parameters for an MIO robot. MacroUSA was then issued a contract for the design and development of two prototype systems, each consisting of one control/display unit and two small amphibious Stingray robots. The Centre required a robot that fits in a Molle pouch with an indicative weight of around 1.5 kg. In terms of mobility it had to be able to overcome normal deck obstacles such as ropes, cables, and anchor chains with height of between 37.5 and 50 mm, and not get stuck on ship deck grating. Ship decks being often contaminated by oil and dirt, the robot needed enough traction to remain in place in those situations and be stable up to sea state 5 on dhows, the traditional sailing vessels used in the Red Sea and Indian Ocean. The robot had to survive a minimum five-metre drop onto a steel deck and be waterproof to one metre, while being floatable and able to move on water, the help of attachable flotation device being admitted.

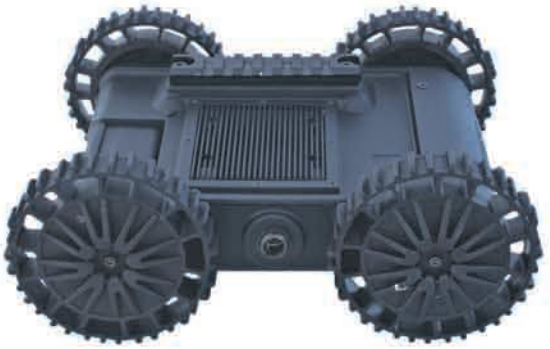
Electro-optical sensors with day/night capability and an audio system, possibly two-way, were also required. A remotely activated strobe distracter capable to attract the opponents' attention or to blind them in the dark was on the list, and so were an attachment for a telescopic extension and a rope, and a single control unit to operate two robots – one steered by the operator, the second performing motion detection to provide rear-guard functions for the team.

MacroUSA happened to have the Beetle in its inventory, which was suitable in terms of dimensions and weight but did not meet many of the other requirements. One of those was ruggedness, the Beetle's aluminium components not being strong enough. Cost and machining issues played against the use of titanium, but in favour of woven carbon-fibre monolithic chassis coupled to aircraft-grade aluminium sides and hardware, woven carbon-fibre wheels and internal brackets, and closed-cell foam for flotation purposes, which allowed to contain weight within 1.8 kg. With height being set by the obstacle crossing capacity (to overcome a 50 mm rope a wheel of nearly double the size is needed) and width being dictated by the battery pack, designers worked on sealed chassis length to provide the required flotation. The Stingray dimensions were thus 253.9 x 205.5 x 95.5 mm, meaning a volume very close to the 4,500 cm^3 threshold established by the customer. This was a key feature as active buoyancy systems were soon discarded, MacroUSA proposing a high-visibility Sling Flotation Device to be wrapped around the Stingray when in-water operations were expected, the system allowing to maintain the robot's ground clearance.

Mobility in water and traction on wet or oily metal surfaces led to a compromise in the wheel configuration, a design with micro-knobby and ducted-paddle propulsion areas being the final solution. A transition belt between the two axles helps to overcome obstacles. The Stingray is equipped with a 50° field-of-view day-night camera that can be tilted ±85°; video and control are automatically inverted when the robot flips over. Infrared and white diode lights are incorporated in the front part of the Stingray. The Picatinny rail can host an extra-payload (max 700 grams) that connects to the robot via an RS232 port. That payload of course negates throwing the robot. The battery provides over two hours of operation and two data links are installed: the coded orthogonal frequency division multiplexing ensures video link while control is provided by the frequency-hopping spread spectrum link. Range is 200 metres in line of sight and 150 metres otherwise. As said initially, the Stingray is an evolution of the Beetle, which remains in the MacroUSA inventory for customers that do not require naval performances.

Given the increasing antipiracy activity carried out by the military, the company is currently awaiting Space and Naval Warfare Systems Command (or Spawar, now a command) to issue the actual contract (the request for quotes covering 200 systems has already been issued).

In the high tier of the light robots category MacroUSA developed the Armadillo, which has been offered in various versions. With a weight of 3.13 kg and 3.70 kg respectively the Armadillo V3.5 and V4.0 remain within the throwable category as both are able to withstand multiple drops from a height of 2.5 metres or horizontal launches to eight metres. They can be operated immediately after launch as they are completely symmetrical, provided no extra payload is added. Both versions are equipped with Picatinny rails and RS-232/485 ports to install and connect sensors or effectors such as disruptors, manipulators or uncooled rotating thermal cameras, to a maximum of three kilos. Both versions have an integrated 360° field afforded



Developed in different variants, MacroUSA Armadillo can be dropped from 2.5 metres, and has been used as the core element by other manufacturers to develop their own robots. (MacroUSA)

The Oto Melara TRP3 has been adopted by the Italian Army as part of its Forza NEC digitisation programme. (Armada/Paolo Valpolini)

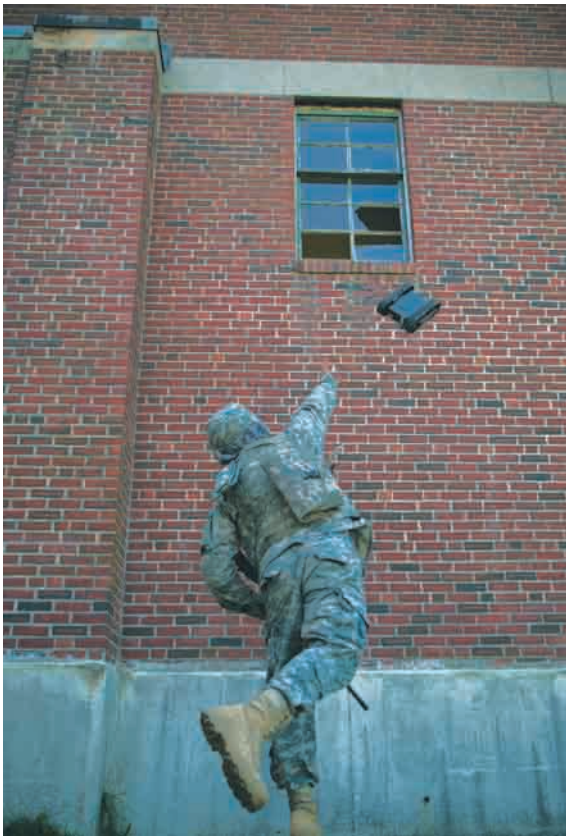
by day/night colour cameras with x2 digital zoom on all sides (the front one can be tilted on theV4.0. Other differences are minor, the V3.5 having two front cameras and front and rear infrared diode lights, while the V4.0 has one front camera and infrared and visible diode lights on all four sides). Both robots are equipped with an audio microphone and optional GPS, as well as a digital accelerometer. MacroUSA uses a COFDM data link working on 1.2-1.4 or 2.2-2.4 GHz frequency bands (many other bands are available as custom options for military customers) and 50 channels, offering an operational range of 300 metres in line of sight and 200 metres otherwise. Equipped with 130 mm diameter rubber wheels, the Armadillos can climb a 45° slope. They can be equipped with a stair-climbing kit that includes fixed flippers with rubber tracks in place of wheels. A further version known as the V4.5 has been developed to offer a higher speed and payload capacity. It features a higher number of payload connectors and has been specifically designed for ordnance disposal. It self rights and is capable of climbing stairs.

With many American programmes cancelled, MacroUSA is looking both at the export market and non-military applications. Some acquisition programmes in Europe, France and Poland, as well as in the Far East are attracting the company's interest.

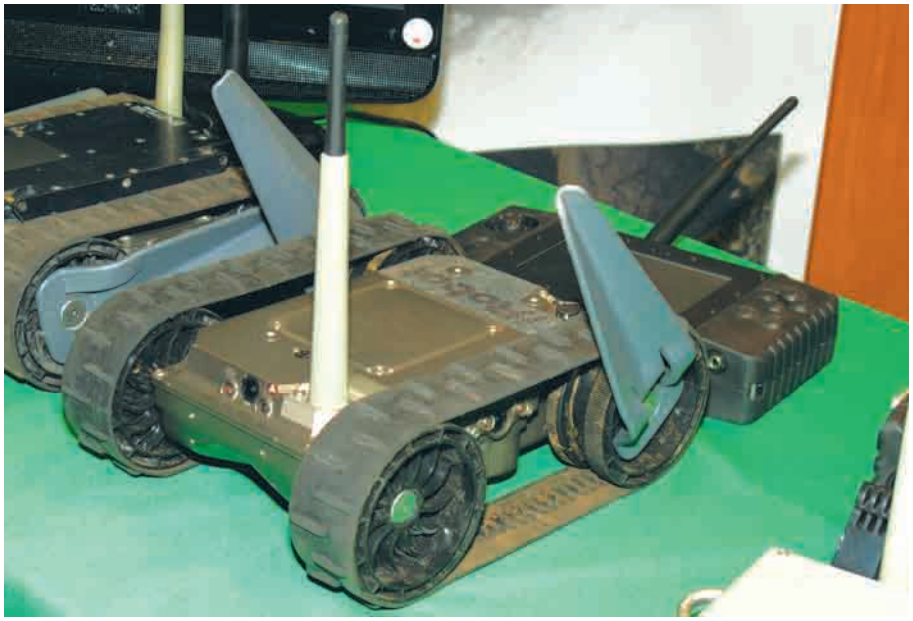
The Armadillo V3.5 was the starting point for Oto Melara's TRP3 robot. The base robot was thoroughly redeveloped in Italy, with the original motors replaced with brushless motors for example. Improvements were also made to the data link, while the portable control unit was redesigned to Italian Army needs. The fixed control station integrated into the Freccia 8x8 vehicle, on the other hand, was designed from scratch by Oto Melara. Based on a ruggedised laptop with a 13-inch screen coupled to a communication box containing the data link, it was also designed to control other ground robots developed by the company as part of the Forza NEC Italian Army digitisation programme. When used via the portable control, the TRP-3 NEC (as it is known) accesses the Forza NEC network via the soldier's software-defined personal radio. When controlled from the vehicle on the other hand, it will exploit the on-board software-defined radio. According to Oto Melara the operational range is 450 metres in line of sight and 200 metres in urban terrain. The robot has obtained its Italian MoD qualification and the first batch of six is being delivered to the Army. The TRP-3 NEC will become the advanced eye of the medium infantry regiments equipped with the IFV version of the Freccia. Slightly lighter than the original V3.5, its dimensions are pretty similar. Its maximum speed is 1.8 km/h and carries six cameras – one day colour and one night camera on the front, day cameras the rear and sides, while a sixth is located on the top of the robot to it to perform inspections under suspect cars. A Picatinny rail has been fitted to the request of the customer for the installation of a laser rangefinder which, with its GPS and digital magnetic compass, enables the TRP-3 NEC to provide the grids of a potential target. The interface can accommodate other types of payloads.

iRobot: This firm's smaller product in the defence field is the 110 FirstLook, a tracked, throwable, self-righting platform that can withstand a drop on concrete from nearly five metres. At 2.4 kg sans payload, the 110 FirstLook is capable of 5.5 km/h, its rubber tracks ensuring good mobility on most surfaces. Submersible down to one metre, it is equipped with two flippers to overcome high obstacles and stairs. Originally those flippers were flat, but at the high temperatures met by the US Army and Marines in Iraq and Afghanistan, they tended to deform, so have since been replaced by stronger 3D flippers.

Built like a game controller to make it intuitive for young soldiers, the ruggedised, water resistant control features a five-inch 800 x 480 resolution display and weighs 0.9 kg. The 2.4GHz band data link (a 4.9 GHz solution is also available) offers a line-of-sight range of 200 metres. For other conditions iRobot developed a specific radio



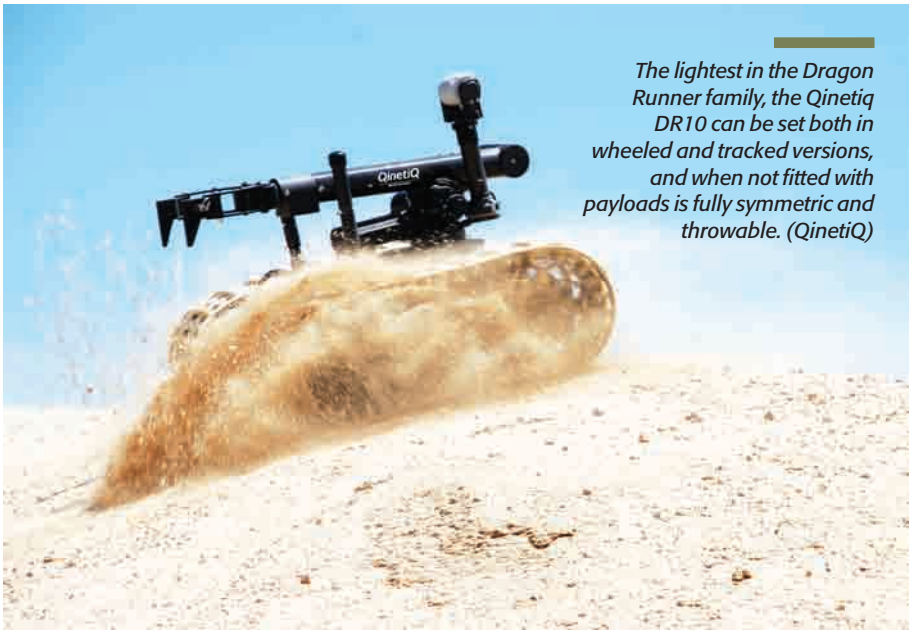
With its 2.4 kg weight the FirstLook can be thrown at a good distance, and yet has sufficient kinetic energy to smash through a window. (iRobot)



In its newest configuration iRobot FistLook has been equipped with new 3D flippers that ensure better resistance especially when operating in high temperatures. (Armada/Paolo Valpolini)

is the Qinetiq North America Dragon Runner 10, the smaller member of the DR family. The chassis can be either wheeled or tracked, shifting from one configuration to the other being a simple and quick operation that is carried out without specific tools, wheels giving place to sprockets and tracks and vice versa. A maximum speed of 6.4 km/h is attained by virtue of an undisclosed number of electric motors that also afford climbing up 100% slopes. The slim body sports a 50 mm ground clearance, a plus when operating on rough terrain. When not equipped with payloads, the DR10 is fully symmetrical and can thus operate as soon as launched.

Developed also in a radio-relay version, the FirstLook has now been provided with a droppable relay that can be left on the ground in the area of operation. (Armada/Paolo Valpolini)



The lightest in the Dragon Runner family, the Qinetiq DR10 can be set both in wheeled and tracked versions, and when not fitted with payloads is fully symmetric and throwable. (QinetiQ)

payload that establishes a mesh connection among the robots. Originally designed to be installed on board the robots, it has now also been redeveloped as a droppable version.

Standard fit on the 110 FirstLook are four visible light to near infrared cameras (hence infrared diode illumination on all sides) with a x8 digital zoom. However, for reconnaissance missions other payloads can be installed on an optional Picatinny rail and accessory port. The company developed its own recce payload, the 400-gram Idac (Integrated Deployment and Camera) that adds a 270° adjustable mast-mounted camera at a height of 155 mm.

The FirstLook also supports numerous NBC sensors such as Smiths Detections' LCD 3.3, RAE Systems' MultiRAE, and Canberra's Radiac. Not subjected to International Traffic in Arms Regulations the 110 FirstLook is in service with the US Army and Marine Corps, and is expanding its international customer base.

Qinetiq: At the upper limit that we have established for mini-robots in terms of weight

The operator can drive the robot thanks to the front and rear day/night cameras, while sounds are picked up an on-board microphone. The DR10 can be used with all QinetiQ control consoles. Not only does the operator see the pictures provided by the cameras but also heading and robot position thanks to the integrated magnetic digital compass and GPS. Line-of-sight range is in excess of 650 metres. Depending on mission and payloads, endurance varies between two and three hours. The DR10 is in service with the US military, and with export customers, among which the United Kingdom.

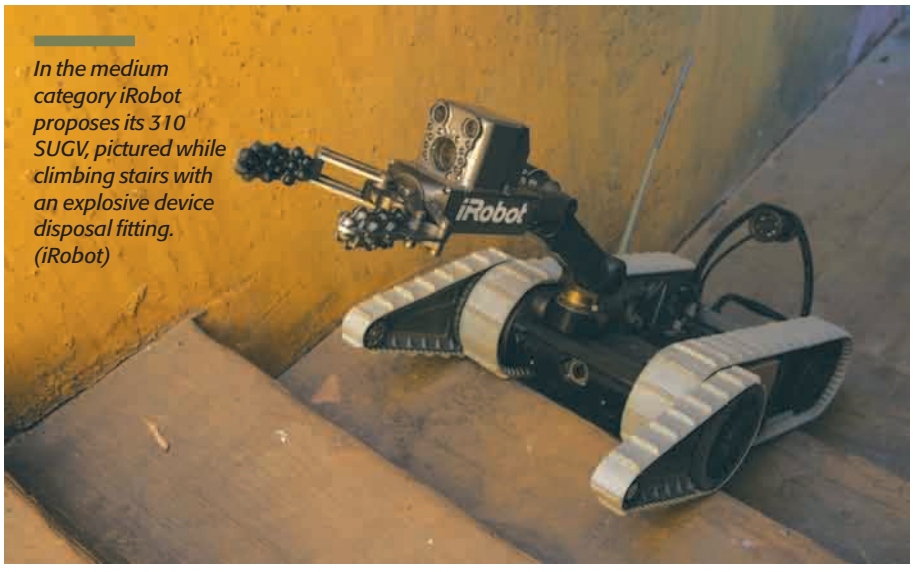
Backpackables and Medium Sized

The medium-sized robots do not gradually step up in size and weight to necessarily be more robust, but simply to enable them to bear more weights, and also make their first steps into some degree of autonomy, although they are still very far from embedding any sort of artificial intelligence.

By acquiring a six-wheel configuration and the ability to launch grenades, the HD member of the Nexter Nerva is also acquiring the nerve for more muscular operations. (Armada/Paolo Valpolini)

iRobot: Besides the small 110 FirstLook seen above, the iRobot catalogue contains bigger robots developed from the original 510 PackBot, thousands of which saw active service in Iraq and Afghanistan. The Ground Combat Systems programme included a small backpackable ground robot that would provide infantry teams with autonomous reconnaissance capabilities in dangerous areas.

The spin-off of the defunct GCS programme is the 310 SUGV that features the typical iRobot architecture with a tracked chassis and tracked flippers that provide good mobility on stairs and other obstacles. The flippers can be removed if a narrower configuration is needed (reducing width from 437 to 348 mm). At 13.2 kg without payload, the 310 SUGV can speed up to 10 km/h and overcome 305 mm-high obstacles, its 2 BB-2557/U batteries ensuring 1.5 hours of operation, though two BB-2590/U batteries will extend this six hours. A wide-angle (107°) front chassis camera with infrared illumination is used to drive the robot, the main sensor for reconnaissance being the arm-mounted low-light colour x10 zoom camera (field of views of between 48° and 5°). The 2.4 GHz data link ensures a 1,000-metre operational range in open terrain, the operator using a wearable controller fitted with Tac-Eye head-up glasses and fame-style hand controller (a ruggedised head-down controller with a 5.6-inch display is available on option). The 310 is in service in numbers in the US military and with export customers.



In the medium category iRobot proposes its 310 SUGV, pictured while climbing stairs with an explosive device disposal fitting. (iRobot)

Slightly bigger and heavier than the previous two, 14.5 kg sans payload, the XM1216 SUGV carries the most effective long range reconnaissance tool among the three robots, a colour camera with a x26 optical plus a x12 digital zooms, as well as a thermal camera with a three-step digital zoom. All those robots can be equipped with a robotic arm for explosive disposal purposes.

The Dragon Runner 20 is the medium-weight champion developed by QinetiQ for the US Marine Corps; here it is fitted with track extenders. (QinetiQ)

Quinetiq: Also in the small unmanned ground vehicle category, Qinetiq North America's Dragon Runner 20 is another multirole recce and explosive disposal system. Originally developed for the US Marine Corps, this 9.07 kg robot has a maximum speed of 6.5 km/h and features day and night cameras at the front and rear, and day-only cameras on the side.

Reconnaissance capabilities can be considerably increased by the addition of a pan-tilt-zoom camera with an omnidirectional microphone and a loudspeaker to ensure two-way communication. It can be fitted with track extenders to improve mobility, as well as with a rear stabiliser for stair climbing.

MacroUSA: In the same category MacroUSA proposes the Scorpion, a nine-kilo tracked robot that can be tossed in the area of interest

MacroUSA Scorpion remains droppable in spite of its nine-kilo weight, its payload capacity being equivalent to its dry weight. (MacroUSA)

thanks to its high impact resistance plastic chassis with aluminium reinforcements.

The standard sensor suite includes a front tiltable day/night colour camera with a 185° field of view and a ±60° tilt angle, with infrared and white diode lighting, a rear fixed colour day/night camera, and an audio microphone. The Scorpion can reach 10 km/h and be dropped from a height of one metre. It can carry a payload equivalent to its weight, including thermal cameras or chemical sensors, as well as explosive manipulators or disruptors.

ECA Robotics: Among the lightest robots in the medium category, the Cobra Mk2 proposed by this renowned French company is a multi-mission platform with a five-kilo payload capacity over a 6.1 kg clean vehicle. The company proposes different payloads, such as a CBRN module with chemical and radiological sensors as well as a radiation dosimeter, an explosive ordnance disposal module with a support that can accommodate different types of disruptors, and obviously an ISR module with a 360° video camera. It also has a ±80° colour CCD camera at the front and a fixed colour camera at the back. Both white and infrared diode lighting is provided, while a microphone and a speaker provide two-way acoustic coverage. Equipped with low pressure tyres, the 4x4 Cobra Mk2 is powered by a 15 V Li-ion battery that ensures a 2.5 hour operating time. Maximum speed is 5 km/h and maximum obstacle height 150 mm. The declared operational range is 250 metres in open terrain, two different control stations being available, one with a seven-inch screen and one with a 10-inch screen, the joystick layout being also different.

One of ECA Robotics' latest developments is the adoption of android tablets or smartphones for control, reducing the soldier's burden as those devices can have multiple uses. This has not been the only improvement, the Cobra Mk2 being now equipped with a GPS that allows to memorise the robot's path, allowing it to come back to the starting point automatically. Tyres with reduced diameter (20 mm less) were adopted to avoid problems when the robot is used to carry out checks under vehicles, and a track kit is now also available to improve mobility on difficult terrains. The launch customer in the military field for the Cobra Mk2 is Canada, which ordered 20 robots with an option on a further 80. Canada required the system to be fitted with a disposable optical fibre guidance system, that allows to operate the Cobra Mk2 to a range of 1,000 metres.

ECA of France developed the Cobra Mk2, with Canada as its military launch customer; the robot can be controlled via dedicated control stations or via cots systems such as smartphones. (ECA)

Robo-team: The MTGR, for Micro-Tactical Ground Robot, was developed by Robo-team in Israel as a multirole robot, but with intelligence, surveillance and reconnaissance as main mission for basic infantry units. For urban use the MTGR is provided with an all-track configuration, while for off-road use it maintains tracks although the adoption of larger diameter wheels that considerably improve mobility in mud, over boulders and on stairs.

This obviously comes at a cost in terms of weight and dimensions, the standard version weighing 7.3 kg while the wheeled-tracked one weighs 8.6 kg, with dimensions also increasing from 455 x 368 x 145 mm to 472 x 470 x 165 mm, but the system remains fully backpackable, however. The MTGR can be put into service in less than 60 seconds by its operator, and can reach a speed of 3.2 km/h; it can overcome a 35 cm obstacle, climb a 45° ramp and 20 cm stairs thanks to tracked flippers that can be added. The MTGR is equipped with five cameras, the front one hosted in a bay and tiltable –20°/+90°, the other being fixed around the body providing a 360° view to the operator. Near infrared illumination is provided all round, while a white diode light is available at the front. The MTGR can be equipped with a manipulator

The Micro-Tactical Ground Robot, MTGR in short, is a multirole robot developed by Roboteam, which can also be fitted with large-diameter wheels. (Robo-team)

Here the MTGR displays its Peeping Tom abilities at night, its articulated tracked system enabling it to adopt somewhat acrobatic postures. (Roboteam)

specifically designed by Robo-team to transform it into an explosive ordnance disposal asset with the addition of a four-degree-of-freedom system with two joints, one gripper and wrist capability. This has a maximum extension of 360 mm and load-bearing capability of 5.4 kg. The arm carries two cameras, one with a x10 zoom and a close camera on the gripper, with both infrared white lighting. Other sensors, such as radiation detectors, sniffers, thermals cameras, etc. can easily be integrated on the platform thanks to a Picatinny rail. The data link adopted features meshing which allows to extend range beyond 500 metres in line of sight, autonomy provided by the battery being of two to four hours. The mesh concept is currently being stressed with new solutions, such as adopting a transceiver in soldiers' vests as well as developing transceivers that the robot can leave behind itself, when entering a culvert or a tunnel for example, to ensure proper connectivity.

As for full autonomy, Robo-team considers that this is still a decade away. However, to make the use of the MTGR as easy as possible for the operator, the company developed a series of pre-set modes for climbing stairs, lifting loads, etc., that considerably reduce human intervention. Typically the MTGR is provided with the Rocu-7 console, which runs on Windows 7 and features a 7-inch touch-screen with a 1024 x 600 resolution. The Rocu-7 features two joysticks, eight hard buttons and four rockers, weighs 2.3 kg with batteries giving a running time of three to six hours. The results of the testing carried out by the US National Institute of Standards and Technology led to the urgent acquisition of an undisclosed number of MTGRs by the US Specials Operations Command, the system being also considered for the green Army to be deployed by standard infantry units. The MTGR is also in service within the Israeli Defence Forces, and Robo-team is strongly promoting its robot worldwide.

Nexter: The heavier member of the Nerva family is the 11 kg HD, for Heavy Duty. It retains numerous features of its lighter brothers but increases its payload capacity to 10 kg. The Nerva HD retains the same data link, one-click concept, two-speed alternative and many of the features developed for the LG and S models, but it can be declined in three different configurations, 4x4, 6x6 and tracked.

The senior member of Nexter's Nerva family is the HD that sports a 6x6 chassis with two slots for payload modules. It is here seen here fitted with a camera and a grenade launcher module. (Armada/Paolo Valpolini)

When used as a 4x4, the robot is fitted with special 300 mm diameter wheels that improve its mobility over rough terrain. In addition, two flippers can be fitted in place of the intermediate wheels and used by the operator to overcome difficult obstacles. In 6x6 operation, the 4x4 wheels are replaced by standard 150 mm diameter wheels, the same as the Nerva LG's, which also accept rubber tracks, in which case the two centre wheels become idlers and only act as roadwheels.

The standard sensor suite includes a front 110° field-of-view high resolution camera with visible and infrared lighting and a rear camera, as well as an omnidirectional microphone. Compared to the smaller robots the HD has a more comprehensive navigation suite, which includes GPS, odometer, magnetic compass, three gyrometers and three accelerometers, the vehicle being differential-GPS compatible. Such precise location data are precious when operating in one of the various semi-autonomous modes available such as waypoints navigation, autonomous patrolling and automatic self-homing. Compared to the Nerva LG, the HD has two slots for Nerva-standard mission kits; mission payloads can however be linked via Picatinny or via a configurable metal plate. The HD is equipped with Ethernet, USB, RS232, digital I/O and video input. Nexter developed a series of mission kits with the Nerva interface, among which is a pan-and-tilt day camera with a x36 zoom for long range reconnaissance, an uncooled thermal infrared camera, an additional battery that allows to double the two-hour autonomy, a bi-directional audio intercom, a smoke generator used as anti-intruder reaction or position indicator, and some CBRN sensors. Transportation modules allow mini-logistic operations, while demining tools can be also provided.

M-Tecks: Another French company, M-Tecks Robotics based in south-western France, developed a series of light ground robots for dual use. The Arthron POD 125A is a symmetrical 4x4 vehicle that can be dropped from 2.5 meters without any problem. Its symmetry is not limited to the physical construction but also expands to its sensors: front and rear ends each carry two colour day cameras and one night camera, and two white diode lights. Power from the hot-swappable 12.8V Li-ion battery offers a 1.5-hour

Developed by M-Tecks Robotics of France the Arthron Pod 125 is a 4x4 adopting a data link that allows to create a mesh with up to 127 robots. (M-Tecks Robotics)

LIGHT | 2.4 | 1.53 | 6

LxWxH: 254 x 229 x 102

110 FirstLook — *iRobot-USA*

LIGHT | 3.7 | 0.83 | 1-2 | 3

LxWxH: 320 x 265 x 130

Armadillo V 4.0 — *MacroUSA-USA*

LIGHT | 3.3 | 1.34-2.82 | 1 | 2

LxWxH: 430 x 280 x 200

Armourdillo — *Robosynthesis-UK*

LIGHT | 1.8 | undiscl. | 1-2 | 0.7

LxWxH: 206 x 175 x 75

Beetle — *MacroUSA-USA*

LIGHT | 5 | 1.79 | 2-3

LxWxH: 394 x 351 x 152

Dragon Runner 10 — *QinetiQ-USA*

LIGHT | 3.76 | 1.11 | 2 | 3.5

LxWxH: 280 x 250 x 110

EyeDrive — *Mistral Group-Israel*

LIGHT | 1.13 | 1.34 | 2-4 | 1

LxWxH: 203 x 229 x 109

Iris — *Roboteam-Israel*

LIGHT | 1 | 1.3 | 2

LxWxH: 216 x 80 x 80

iSnoop — *Optimess-Germany*

LIGHT | 4.5 | 1.11 or 4.17 | 1-2 | 6

LxWxH: 350 x 310 x 150

Nerva-LG — *Nexter-France*

LIGHT | 2 | 1.11 or 4.17 | 4 | 1

LxWxH: 210 x 300 x 150

Nerva-S — *Nexter-France*

LIGHT | 0.6 | 0.69 | 1.5

LxWxH: 180 x 120 x 56

NovaCTR — *Novatiq-Switzerland*

LIGHT | 2.8 | 2.77 | 2 | 2.5

LxWxH: 240 x 220 x 100

NovaMRR — *Novatiq-Switzerland*

LIGHT | 2.5 | 1.95 | 2 | 2.5

LxWxH: 260 x 216 x 110

NovaSRR — *Novatiq-Switzerland*

LIGHT | 0.8 | 0.69 | 1.5

LxWxH: 194 x 190 x 100

PocketBot — *Novatiq-Switzerland*

LIGHT | 0.56 | 0.3 | 1

LxWxH: 142 x 194 x 76

Reconscout IR — *ReconRobotics-USA*

LIGHT | 0.64 | 0.6 | 1

LxWxH: 300 x 216 x 140

Reconscout XL — *ReconRobotics-USA*

A COMPENDIUM OF LAND ROBOTS,

LIGHT | 2.9 | 1.34 – 2.82 | 1.5 - 3 | 2.5

LxWxH: 400 x 295 x 130

Roboforce 1 — *Robosynthesis-UK*

MEDIUM | 9 | 5-7 | 2 | 1

LxWxH: 600 x 250 x 120

Arthron 4075 A — *M-TeckRobotics-USA*

LIGHT | 1.8 | 0.7

LxWxH: 241 x 190 x 95

Stingray — *MacroUSA-USA*

MEDIUM | 6.1 | 1.39 | 2.5 | 5

LxWxH: 364 x 392 x 170

Cobra Mk2 — *ECA-France*

LIGHT | 4.45 | 1.95 | 2-4 | 5

LxWxH: 370 x 334 x 150

StoneMarten — *Novatiq-Switzerland*

MEDIUM | 9.07 | 1.78 | 3-4

LxWxH: 508 x 381 x 178

Dragon Runner 20 — *QinetiQ-USA*

LIGHT | 0.54 | 0.46 | 1

LxWxH: 209 x 193 x 114

Throwbot XT — *ReconRobotics-USA*

MEDIUM | 9.5 | 0.42 – 1.67 | 6-12 | 10

LxWxH: 620 x 440 x 200

EXTRM — *Robosynthesis-UK*

LIGHT | 1.4 | 0.86 | 1 | 0.16

LxWxH: 205 x 167 x 190

TRM — *PIAP-Poland*

MEDIUM | 7.26 | 0.9 | 2-4 | 9.1

LxWxH: 455 x 368 x 145

MTGR — *Roboteam-Israel*

LIGHT | 3 | 0.50 | 3 | 3

LxWxH: 300 x 260 x 130

TRP-3 — *Oto Melara-Italy*

MEDIUM | 11 | 1.11 or 4.17 | 2 | 10

LxWxH: 650 x 450 x 300

Nerva-HD 4x4 — *Nexter-France*

MEDIUM | 13.2 | 2.78 | 6

LxWxH: 708 x 348 x 229

310 SUGV — *iRobot-USA*

MEDIUM | 11 | 1.11 or 4.17 | 2 | 10

LxWxH: 650 x 450 x 150

Nerva-HD 6x6 — *Nexter-France*

MEDIUM | 6,4 | 4.17 | 1.5 | 1

LxWxH: 390 x 307 x 170

Arthron 125A — *M-TeckRobotics-USA*

MEDIUM | 13.69 | 2.78 | 4

LxWxH: 686 x 516 x 406

PackBot 510 — *iRobot-USA*

FROM THROWABLES TO TRUCKS

MEDIUM | 5.9 | 1.11 | 4 | 8

LxWxH: 435 x 327 x 185

Scorpio — *Tecdron-France*

MEDIUM | 9 | 2.78 | 1-2 | 9

LxWxH: 557 x 485 x 221

Scorpion — *MacroUSA-USA*

MEDIUM | 14.52 | 2.78 | 6 | Undiscl.

LxWxH: 607 x 348 x 165

XM 1216 SUGV — *iRobot-USA*

MEDIUM | 7.5 | 0.42 – 1.67 | 1.5-3 | 8

LxWxH: 580 x 390 x 200

Robocube 4x4 — *Robosynthesis-UK*

HEAVY | 2 | 8 | 75

LxWxH: 1450 x 840 x 600

4MOB — *Sterela-France*

HEAVY | 1,746 | Undiscl. | 1,088

LxWxH: 914 x 419 x —

AvantGuard — *G-NIUS-Israel*

HEAVY | ?? | 2.35 | 20 | > 350

LxWxH: 1524 x 813 x 1194

CaMEL — *Northrop Grumman-USA*

HEAVY | 26 | Undiscl. | 3 | 20

LxWxH: 627 x 594 x 134

Cayman — *Tecdron-France*

HEAVY | 43 | 1.39 | 2-3 | 20

LxWxH: 850 x 650 x 300

Guard Bot — *Marsch Systems-Germany*

HEAVY | 1400 | 13.9 | 24 | Undiscl.

LxWxH: 2950 x 1800 x 2200

Guardium Mk.1 — *G-NIUS-Israel*

HEAVY | 1200 | 13.9 | 24 | 400

LxWxH: 3420 x 1800 x 2200

Guardium Mk.2 — *G-NIUS-Israel*

HEAVY | 3000 | 33.3 | 2000

LxWxH: 5000 x 2000 x 2200

Guardium Mk.3 — *G-NIUS-Israel*

HEAVY | 1200

LxWxH: **

HMV — *G-NIUS-Israel*

HEAVY | 120 | -------undisclosed-------

LxWxH: 1200 x 980 x ??

Lynx-C — *JELS-Jordan*

HEAVY | 167 | 3.13 | 8-12

LxWxH: 940 x 635 x 914

MAARS — *QinetiQ NA-USA*

HEAVY | 2.35 | 20

LxWxH: 1524 x 813 x 635

MADSS — *Northrop Grumman-USA*

HEAVY 1,100 | 9.72 | 10 h/250 km | 250

LxWxH: 3000 x 1800 x 1260

MRK-002-BG-57 — *Russia*

HEAVY 120 | 3.35 | 6-12 | 250

LxWxH: 1067 x 762 x 432

Probot — *Roboteam-Israel*

HEAVY 510 | 2.22 | 100 | 340

LxWxH: 1930 x 900 x 1067

Protector — *HDT Global-USA*

HEAVY 29 | 3.89 | 4 | 50

LxWxH: 750 x 650 x 277

Quator — *Tecdron-France*

HEAVY 260 | 2.22 to 4.17 m/s | 8 | 500

LxWxH: 1250 x 1150 x 820

Quator XL — *Tecdron-France*

HEAVY 764 | 480 | 794

LxWxH: 3860 x 1498 x 1930

Raider II — *QinetiQ-USA*

HEAVY 160 | 3.33 | Undiscl. | 250

LxWxH: 1600 x 800 x 750

Rex — *IAI-Israel*

HEAVY 250 | 2.78 | 4 | 150

LxWxH: 1500 x 800 x 800

Robas — *Gate Elektronik-Turkey*

HEAVY 700 | 11.11 | 300 km/80 km | 500

LxWxH: 3400 x 1640 x 1075

Robbox — *SERA-France*

HEAVY 215 | 1.81 | 8 | 200

LxWxH: 1370 x 765 x 500

Scarab LX — *Tecdron-France*

HEAVY 1,955 | 7.22 | 200 | 682

LxWxH: 3400 x 2000 x 1800

SMSS — *Lockheed Martin-USA*

HEAVY 80 | 4.17 | 4 | 20

LxWxH: 1153 x 599 x 890

TRP-2 Combat — *Oto Melara-Italy*

HEAVY 300 | 2.78 | 4 | 100

LxWxH: 1250 x 600 x 800

TRP-2 HD — *Oto Melara-Italy*

HEAVY 60 | 4.17 | 3 | 30

LxWxH: 1220 x 580 x 460

TRP-2 Rista — *Oto Melara-Italy*

KEY

CATEGORY: LIGHT, MEDIUM, HEAVY — weight, kg

PERFORMANCE: speed, m/sec; endurance, hrs

CAPACITY: kg

POWERPLANT: diesel, electric, hybrid

WHEELS: 2, 2+1, 4, 6, 8

TRACKS & TRACKS OVER WHEELS

Arthron R 4075 has a peculiar architecture, the modules being linked by a universal joint system that enables its 8x8 chassis to steer and bend to improve mobility. (M-Tecks Robotics)

running time. Maximum speed is 15 km/h with standard 170 mm diameter wheels. Wheels can be changed for particular terrains although no quick-change system was considered for various reasons, one of them being strict cost control.

The POD 125A data link ensures operations up to 300 metres in open terrain and 200 meters in urban areas; however the communications architecture has been designed for swarm operations, thus the full potential of the M-Tecks Robotics ground robot is obtained when multiple vehicles are deployed on the ground. Each of them will act as the node of a mesh, thus increasing range and flexibility, especially in urban canyons; each robot is equipped with a GPS and up to 127 robots can be used to form a mesh. Active also in pipe-inspection robots, M-Tecks Robotics retained wire-command for its recce robots, the POD 125A having the option of being operated by wire to a range of 30 metres.

In its quest for improved mobility on rough terrain, M-Tecks Robotics developed a bigger, nine-kilo reconnaissance robot. Known as the R 4075A this 8-wheeler's architecture is quite peculiar in that it is composed of four one-axle modules that are linked to each other via a universal joint that distributes main motor drive to all wheels. The multiple-articulated structure was developed in the course of a five-year research effort, and considerably improves steering and bending, and thereby obstacle crossing and mobility by a factor of three. One of the intermediate wagons hosts the main motor while the other house the main battery – a standard 15V 6800 Ah NiMh providing two hours of operation. The two end modules each carry two auxiliary motors that ensure relative motion between those and the previous module, thus providing agility to the polyarticulated structure to obtain maximum mobility on difficult terrain. The R 4075A can cope with 300 mm high obstacles and 270 mm long gaps, and climb up 100% slopes. Standard wheels have a 140 mm diameter, and different type of tyres can be mounted.

Two daylight cameras, the upper one oriented upwards and the lower one oriented downwards, allow for a combined 160° vertical field of view, the single night camera being oriented horizontally, while two white diodes ensure better illumination when needed. Video transmission is ensured thanks to a 2.4 GHz link, while commands are provided via an 869 MHz link, range being of 300 metres in open terrain and over 100 metres in urban terrain. Like its smaller brother the R 4075A has a wire-command option, here up to 50 metres. Operational modes include semi-automatic remote control, which considerably reduces the operator workload, and even an automatic mode. Video-stabilisation software is available, as well as a camera-dome containing a colour or a thermal camera.

Both the POD 125A and the R 4075A are controlled by a 2.5 kg console sporting a nine-inch screen and a joystick. Currently the prototypes of both systems are being tested by the French DGA, lessons learned from those tests being integrated in the designs that are both still in the development phase.

Robosynthesis: This company's modular system described in the "light" ground robots section, can of course be used to generate bigger and heavier robots. An example of that is the EXTRM platform, a 9.5 kg multi-mission system the maximum speed of which ranges from 1.5 to 6 km/h depending on the mobility system used. With an overall height of only 200 mm (the diameter of the wheels), it can overcome 450 mm high obstacles when fitted with the tail dragger, cope with 40° lateral slopes and climb a 50° slope, providing grip is sufficient.

It can be fitted with a 2.4 or 5.8 GHz data link providing a 1000-metre operating range, and is powered by two rechargeable Li-ion batteries, either BB2590/U or BB2557/U, that provide respectively 12 or 3 hours of endurance. The operator drives the robot using the images provided by an infrared-illumination sensitive, fixed focus, wide angle 640 x 480 resolution camera, while a

With its modular system Robosynthesis developed the EXTRM, which can be equipped with a tail dragger to allow it to overcome higher obstacles. (Robosynthesis)

Shown at Sofex 2014 the Robocube is another medium-size robot that features eight sockets for installing extra batteries or payloads. (Armada/Paolo Valpolini)

Detail view of the Universal Socket developed by Robosynthesis to allow instantaneous mechanical, electric and data coupling of payloads. (Armada/Paolo Valpolini)

pan-tilt-zoom optronic set is also available for reconnaissance purposes; the latter features four integrated micro-cameras with different focal lengths, thus providing a stepping zoom effect with field of views of between 7.5° and 60°, while the 0.008 lux sensitivity ensures good images even in very low light conditions.

As with all Robosynthesis systems, the latest version of EXTRM is fitted with a number of Universal Sockets that can accept payloads of different kinds. At Sofex 2014 the Company exhibited the Robocube 4x4; lighter and smaller than the EXTRM, it features six topside universal sockets and two lateral ones.

Tecdron: Again from France, Tecdron has a considerable portfolio of ground robots, from light to heavy. The Scorpio is a three wheeler tactical remote-control robot that falls in the medium category with its 5.9 kilos; in August 2013 when the programme was launched the company gave priority to toughness, image quality and transmission range from the outset, which led to a robot that is slightly heavier than others developed for similar missions. With a chassis entirely

Relatively heavy for a three-wheel robot, Tecdron's Scorpio was designed with robustness as a key parameter. (Tecdron)

built in aeronautical aluminium, the Scorpio is fully waterproof to two metres depth and treated against corrosion. It can be launched out to ten meters distance without any risk of breaking its components. It is powered by two electric motors, the rear wheel only having a stabilisation role, and can climb a 35° slope and cope with a 30° side slope; its 180 mm diameter rubber wheels allow it to overcome 140 mm obstacles and provide good mobility on difficult surfaces such as mud, gravel or sand. A 12 Volt 5.8 A/h Lithium-ion battery ensures a four-hour endurance; a second battery is offered on option allowing to double the endurance.

Equipped with a wide-angle day/night tilt-zoom camera at the front, it is fitted with infrared diode lighting as well as with a microphone for audio recording. Images and audio are transmitted via a digital data-link to the mini-control station which includes a five-inch display, a joystick and a series of push-buttons. Operational range in line of sight is 300 metres while in urban terrain and inside building this is reduced to 100 metres. The Scorpio can carry up to eight kilos of payload, although this is not its principal aim. For the time being it has been sold to the French National Police, mostly for its special units that tested it for months. In the military it has been tested by French special forces, its weight being the only drawback when considering its tactical use. The smaller platform, the Vixen, has been put on stand-by as Tecdron is currently improving it in many ways and a prototype of the new configuration is expected in late 2014.

Heavyweights: the Infantrymen Sherpas...

A category of ground robots is emerging to ease the burden off the infantry team's shoulders. Those systems are capable of carrying a heavy load thus can follow a squad on the field letting the soldier just with his day-sack, while bearing the heavier bergens. Another typical task for those robots is for them to replace inhabited vehicles in dangerous missions, such as ammunition resupply on the frontline, or Casevac missions from the troops-in-contact area to a safer zone.

While legged robots might be the better solution to ensure a mobility close to that of a human soldier, for the time being heavy robots designed for logistic purposes remain fitted with wheels or tracks. (DARPA)

In addition to the above, recce packages, even installed on telescopic masts, as well as explosive ordnance disposal gear with robotic arms and disrupters, can transform these platforms into specialised vehicles with the advantage of being easily reconfigurable again for other missions in a very short time. Their level of autonomy as well as their mobility can vary consistently: most of the solutions currently available are based on wheels, which provide an average mobility on rough terrain, tracks being more noisy and complex. For the time being, legged solutions have been tested at experimental level, as in the case of Darpa's Legged Squad Support System (LS3).

The LS3 is a highly mobile, semi-autonomous legged robot capable to interact with the troops. The six legged platform aims at a degree of mobility comparable with that of the human being, avoiding reducing the options for the troops on foot. Electrically powered, the LS3 can carry 180 kg over 32 km, and does not need any intervention for a 24-hour period. The platform is under test since July 2012 by the US Marine Corps and the US Army. Its three main autonomous modes are the following:

- leader-follower tight, where the platform attempts to follow as closely as possible the path of its leader;
- leader-follower corridor, in which the LS3 follows the leader while maintaining

a greater freedom to make local path decisions and

• go-to-waypoint, whereby the system's local perception allows it to avoid obstacles on its way to a location designated by GPS grids.

• The testing phase was due to last two years and should thus be close to completion.

Lockheed Martin: This company's Squad Mission Support System, SMSS in short, is the only "mule" type ground robot that can claim to be combat proven. The system was selected in 2011 by the US Army for its Project Workhorse trial and four SMSS were deployed downrange in 2012. These obtained a great success among troops who asked for them to remain in theatre. Their capacity to carry nearly 700 kg of supplies while autonomously following troops proved extremely valuable, and at least in one case the system was overloaded with more than one tonne of materiel and worked flawlessly.

Developed around 2005 and continuously updated, the SMSS is based on the PFM Manufacturing Inc. Land Tamer 6x6 XHD built in marine grade aluminium and powered by an 80 hp turbodiesel engine. The figures provided for the Block 1 version call for a 1,955 kg gross vehicle weight, a 682 kg load-bearing capacity, the vehicle being air transportable inside CH-53 and CH-47 helicopters, or under a sling by a UH-60. Lockheed Martin concentrated on adding autonomy capabilities, the SMSS being able to operate in various modes such as manual drive, remote operation, voice command, return to operator, go-to-point via selected waypoints, return via the generated path, GPS waypoint navigation, follow-person and follow-vehicle.

While US Army personnel tried to retain the SMSS in theatre due to its usefulness, both the Army and Lockheed Martin pursued the development of other mission packages and tested them in the field. This went from forward deployment reconnaissance capabilities using a satcom link, to route clearance using a roller-rake system. In both cases a Lockheed Martin 9" Gyrocam was installed on a mast providing long range reconnaissance or allowing to identify suspect areas where bombs might have been planted. A route clearance test was carried out equipping the SMSS with a roller-rake system, while satcom-controlled missions were also tested in America involving command ranges of over 300 km distance. Overall Lockheed Martin built eight SMSS, the last two to a "Block 2" standard, though no details having been released on the upgrades.

Lockheed Martin's Squad Mission Support System (SMSS) has been used in Afghanistan as a mule but it is now also proposed as a reconnaissance asset. (Armada/Paolo Valpolini)

In August 2014 Lockheed Martin carried out a demonstration, in co-operation with the U.S. Army Tank Automotive Research, Development and Engineering Center, that involved two of its uninhabited systems, the K-MAX helicopter, developed with Kaman, and the SMSS equipped with a Gyrocam optical sensor. The unmanned package mission was to resupply a group of soldiers defending a village. The K-MAX flew the SMSS in the vicinity of the village, the robotic system reaching the soldiers providing the required supplies. The 8x8 semi-autonomous vehicle then reached an observation point where it used its mast-mounted 9" Gyrocam sensor to scan the area looking for enemy forces. Both the SMSS and the K-MAX were equipped with mobile satcom systems as well as local line-of-sight communications systems. Further developments might see the adoption of a new platform, the development of a less-than-lethal and/or lethal capacity with a turret and the shift from semi-autonomous to fully autonomous movement capability.

Northrop Grumman: This company developed the Carry-all Modular Equipment Landrover, or Camel in short, to provide logistic support to patrols on foot. The system is a 6x6 platform that can be easily fitted with rubber tracks over the wheels when needed. Each wheel is powered by an electric motor fed by a diesel-electric generator. The engine runs on diesel fuel or JP8, and its 13-litre tank ensures over 20 hours of operation; such a solution allows for quiet movement when close to potential danger. It has a maximum speed of eight km/h, can climb 40% slopes, move across 20% side slopes, overcome 0.3-metre obstacles and fords. Its load, nested in a tubular structure mounted on the chassis, can be in excess of 350 kg.

Northrop Grumman's Camel 6x6 can carry over 350 kg of supplies and can be quickly fitted with rubber tracks. (Northrop Grumman)

The Mobile Armed Dismount Support System is the weaponised version of the Camel, seen here during firing trials, with a detailed view of the installation in the insert. (Northrop Grumman)

The Camel is equipped with an obstacle detection and avoidance sensor package. It can be guided in tethered or follow-me mode. In a convoy they will follow each other in wagon train mode. Numerous optional kits are offered in addition to the above-mentioned tracks, like an extended-range external battery pack, interchangeable data links, fibre optics, hard-line cable or radiofrequency systems. According to the company both the US Army and the Socom have shown a great deal of interest in the platform in its base configuration as well as in armed configurations described later in this Compendium.

HDT Global: The Protector tracked robot is developed by HDT Global as a multirole support system for soldiers on the field. Powered by a 32 hp diesel engine it can carry a 340 kg payload plus pull another 225 kg on an associated trailer. The Protector can be quickly disassembled in man-portable modules to allow to cross unforeseen obstacles. Its 57-litre fuel tank (JP8 or diesel) is good for a 100 km endurance. The protector's maximum speed is eight km/h. The base vehicle is remotely controlled and a cruise-control mode allows to reduce the operator's workload.

HDT also demonstrated that its robot can acquire some level of autonomy with a semi-autonomous navigation based on data from multiple sensors including electro-optics, active radio-frequency identification tags, lidar, differential GPS, attitude heading reference system, and drive sprocket odometer on each track. For increased safety in follow-mode operation at least two of the sensors must agree on the location of the leader before the Protector follows. The system has a hydraulic power outlet for accessories and a 2kW electric power output. In addition to its usefulness in route clearance and explosive disposal operations (which are not the purpose of this Compendium) the Protector can be fitted with a back hoe and a front loader to contribute to the creation of post and base protections (filling gabions with earth, etc.) and then return on patrol duty with the troops. A Casevac configuration with two stretchers, a version with a tethered drone for surveillance, and an armed version with an M-153 Crows remotely controlled weapon station have also been demonstrated. The wireless remote control has a thumbstick and two buttons.

A multirole robotic system, the Protector developed by HDT Global is seen here in a logistic transport mode. (HDT)

Its weight and its payload capacity allow the Protector to be transformed into a weaponised platform, equipped here with a Crows weapon station. (HDT)

In Israel two companies have developed a wheeled carrying platform, Israel Aerospace Industries and Robo-team.

IAI: Israel Aerospace Industries' Lahav Division has developed a robotic platform known as the Rex, a 4x4 powered by a diesel engine. It can hit 12 km/h carry up to 250 kg over a dry weight of between 160 and 200 kg. Its first role is to support foot patrollers by carrying part of the soldiers' burden. The robot can be operated in three different modes. The simpler is remote control. The second sees the use of a mechanical leash held by a soldier, the Rex following him along the path. The smartest mode is the follow-me by virtue of which the robot follows the path of the soldier whose

IAI Lahav Division developed the Rex, a 4x4 platform capable to carry up to 250 kg payload. A new version will see this figure increased to at least 300 kg. (Armada/Paolo Valpolini)

With nearly 250 kg of payload Probot can be used for resupply or casevac missions, sensor kits and explosive disposal kits also proposed by Robo-team. (Robo-Team)

coordinates are sent via radio to the Rex, which follows the waypoints provided by its on-board GPS. If more payload carrying capacity is needed a group of Rex can be used in this mode. Although not implemented on the prototype, the Rex can be equipped with a route recording mode to enable it to return to its starting point, a mode that could be of use for repeating a re-supply route and perhaps more importantly to bring back a casualty.

The Rex is not only proposed for logistic support, but also for other duties, such as reconnaissance with a package that includes a gimballed electro-optical sensor. The Rex prototype has been evaluated by the Israeli Defence Forces as well as by foreign armies, whose feedback led to the development of a second generation Rex. One of the main alterations affects size and weight: the new robot will have a payload capacity of at least 300 kg over a weight increased to 230 or 250 kg. Operating modes will remain similar, IAI considering that increasing the level of autonomy would considerably increase costs, which goes against the company marketing strategy. What will definitely evolve is the propulsion system, the second-generation Rex being fitted with a diesel-electric pack that allows "silent creeping" when stealthiness is a must. According to IAI the prototype of the new-version Rex will be ready for trials in late 2014.

Robo-Team: Already seen earlier in this Compendium, Robo-Team in this category offers a system known as the Probot (Professional Robot), and features an electric 4x4 chassis, with load-carrying capacity more than twice its 120 kg weight. Electric propulsion was chosen to ensure maximum aural stealthiness, compared to the much noisier robots in this class powered by petrol or diesel engines. Its maximum speed of 7.5 km/h allows it to easily follow troops on foot, while its capacity to climb 23 cm obstacles and stairs ensures sufficient cross-country mobility. The Probot is equipped with 360° day/night vision with one camera per side and a 360° near-infrared illumination module. The front camera can be tilted 45°/+90° and is equipped with a x10 zoom, while the lighting system features also a white diode light. 12V or 28V is available as are Ethernet RJ45 and RS232 ports to interface payloads with the on-board computer.

Robo-team proposes packages such as a bomb disposal kit that includes a heavy weight manipulator, a recce kit, CBRNE and HAZMAT detection kits, and so forth. The Probot is equipped with a 1,000-metres line-of-sight data link. In addition the platform is equipped with tracing and imaging sensors for hands-free navigation in urban, indoors and open spaces, a follow-me system allowing the Probot to follow automatically the infantry squad it is assigned to. Robo-team is not much talkative on those details as the Probot is still being developed, with a number of prototypes currently in the hands of potential customers to obtain feedback before moving to production. The company is of course working on autonomy packages that might easily find their place on the Probot given its size and payload capacity.

Quinetiq: In recent years Qinetiq North America developed numerous ground robotic systems belonging to the heavy category for different purposes, route clearing, reconnaissance, combat, etc.

For support missions the company developed solutions aimed at robotising existing vehicles. Its Robotic Appliqué Kit (RAK) was designed in such a way it can be installed in about 15 minutes on 17 different models of Selectable Joystick Controlled (SJC) Bobcat loaders to be used in various types of missions, mostly related to route clearance such as the Minotaur and the Raider I, or the Spartacus combat engineer tool. To provide logistic support to infantrymen QinetiQ North America developed the Raider II with Polaris Defense, since the vehicle is based on the Military Diesel Crew Long Box. It can still be operated by a soldier in which case it can reach a maximum speed of 55 km/h. Otherwise the Raider II can be used in remote-operation or the autonomous modes. In the first instance it is controlled via the one-kilometre range Tactical Robotic Controller; in the second different behaviours are available such as obstacle detection, obstacle avoidance, follow-me, waypoint navigation and return home. A daylight and a 640 x 480 thermal camera with pan, tilt and zoom are installed on the roll cage, while four camera pods provide 360° coverage. Soldiers can hang up to 10 rucksacks cage sides, while two litters can be secured on the flatbed for medevac purposes.

Transforming ATVs in unmanned systems is not new: Boeing UK and John Deere developed a similar system some years ago called the R-Gator A3 with a load bearing capacity of 635 kg.

Sterela: Tasked with the development of the Air Cobot chassis, (Cobot being the somewhat convoluted acronym of Aircraft enhanced Inspection by SmaRt & Collaborative robot), Sterela, of France, exhibited its new platform at Eurosatory 2014 in a mule role. A four-wheel drive chassis the 4MOB is equipped with all embedded and remote emergency shutdown systems required in industrial environments, including obstacle detecting bumpers. It has a 100 kg capacity, has a 200-metre range data-link, is powered by electric motors, and Li-ion 48 V battery pack affords it an eight-hour endurance.

Differentially steered, the Sterela platform can work in follow-me mode, or follow a pre-programmed path, the latter being offered as option. Its standard speed is 7 km/h; however an optional booster can pump this to 18 km/h.

Sterela of France developed a 4x4 robotic platform for airport use, and is now proposing it as a logistic platform for military applications. (Armada/Paolo Valpolini)

Sera Ingénierie: A French company part of the Sogeclaire Group, Sera Ingéniérie received from the French DGA a contract for the development of a robotic vehicle as part of the Rapid programme, the acronym standing for *Régime d'Appui Pour l'Innovation Duale,* which is support regime for dual innovation. The architecture being associated with transport requirements, the resultant robot known as the Robbox is composed of an upper beam that links the two automotive units, which can be either diesel or electric. The diesel unit is equipped with a 16.75 hp

Sera of France developed a wheeled robotic platform known as the Robbox consisting of two powered units and a central beam, seen here in a sensor carrier version fitted by MBDA. (Armada/Paolo Valpolini)

Nexter adopted Sera's Robbox as the base for its mule concept, a weaponised version being apparently also considered. (Armada/Paolo Valpolini)

engine while the electric unit features a 15 kW electric motor and a 6 kWh Li-ion energy pack. Depending on the choice one or both axles are steerable. In the second case the turning radius drops from 5.4 to 3.4 metres, which equates to turning on a penny since this is the Robbox's length. The maximum on-board power available for a payload is 2kW, its maximum weight being 500 kg. This can be distributed in two modules: the upper one with maximum dimension of 2400 x 1200 x 400 mm, while the lower one must be smaller than 1200 x 1500 x 550 mm. This leaves 250 mm of ground clearance to allow good mobility on obstacles.

Nexter's exhibit was the Mule, featuring a top tray and a low floor case, able to carry 300 kg, but combined maximum weight is limited to 400 kg as with the structures and systems installed the robot's empty weight is increased to 800 kg, somewhat altering some of the performance parameters. The key intervention from Nexter is the add-on C2 suite, which includes differential GPS, odometer, magnetic compass, gyrometers, accelerometer and laser sensors for navigation and a scanning laser for obstacle detection. The software developed allows, beside standard teleoperation mode, automated modes such as waypoints following, path record and replay, follow me, etc. Delivered just before the Eurosatory exhibition, the Robbox will start mobility tests in September 2014. Nexter plans to start operational evaluation tests in early 2015; the aim is first to verify the various autonomous modes, in particular *follow-me*, as the French DGA intends to use the Mule to develop the operational doctrine for robot-equipped units. Under investigation are thus advanced modes that would allow the soldier to "ask" the robot to stop, wait, join the infantry team, and so on, in order to provide a truly effective support to a ten-man combat group. Nexter aims at developing a multirole ground robot, meaning that a weaponised version already seems to be in the pipeline.

MBDA, on the other hand, was proposing the Robbox in an M2R configuration, a multi-sensor platform for air defence. In that configuration the Robbox is turned into an air defence system that can be deployed in dominant positions without risking soldiers' lives. The M2R is equipped with an infrared search and track Spynel-X developed by HGH Infrared Systems of France to capture full panoramic images at 120 Mpix resolution with a detection range of 16 km. Once the threat is detected and tracked by the Spynel-X an optronic sensor with day camera and thermal imager, equipped with a hefty zoom, provides positive identification. In Paris the robot was exhibited with a mast-mounted Flir Systems Ranger MS. Those sensors can also be deployed to ensure ground surveillance.

...AND RECCE AND FIRE SUPPORT PROVIDERS

The last few lines of the last paragraph have already led us into a field that somewhat steps beyond the pure logistical use of heavy ground robots. Here is more on that theme.

G-Nius: The company that has the longest

field experience in heavy patrol and armed robots is certainly G-Nius, the Israeli joint venture between Elbit Systems and Israel Aerospace Industries. Its first Guardium, later renamed Guardium Mk.1, entered service in 2007. Based on a Tomcar all-terrain vehicle chassis, the Mk.1 was logically followed by the Mk.2, based on a chassis of the same origin but with a 400 kg payload capacity, which gave it a mule role. The Mk.3 followed, based on a Ford F-350 pick-up. The original Guardium is still used to patrol the Ben Gurion airport in Tel Aviv, the Israeli Defence Forces having acquired numerous G-Nius robots.

The Robbox can climb a 40% slope and overcome 250 mm vertical obstacles. Its top speed in remotely controlled mode is 40 km/h. In full diesel mode its autonomy reaches 300 km, dropping to eight km/h in full electric mode. Sera Ingégnerie delivers the Robbox with three different levels of command and control suite, from the very basic including only actuators, to a medium version with a data link, six cameras and a command console, to specific configurations, developed with third partners. Two of those partners, Nexter and MBDA, exhibited the Robbox in two different configurations at Eurosatory.

G-Nius Guardium Mk1 has been in service for years to provide security along the Tel Aviv Ben Gurion airport perimeter. (G-Nius)

G-Nius Guardian Mk2 features a cargo area that can carry up to 400 kg of supplies, which allows to use it in a mule role. (G-Nius)

The Hybrid Multipurpose Vehicle (HMV) is the latest iteration of the G-Nius line of robots and was unveiled at Eurosatory 2014. (Armada/Paolo Valpolini)

Based on the Dumurs Tactical Amphibious Ground Support vehicle G-Nius AvantGuard Mk1 is shown here with an Elbit Systems RCWS. (G-Nius)

A more combat-oriented development is the AvantGuard, based on a Dumur Tags vehicle (Tactical Amphibious Ground Support), a 1.75-tonne, four-track chassis powered by a Kubota 100 hp turbodiesel engine providing a maximum speed of 20 km/h. The four tracks, each 0.91 metres long and 0.42 metres wide, ensure a low specific ground pressure and optimal mobility. With a one-tonne load-carrying capacity various types of modules can be installed, including remotely controlled weapon stations. This robot was renamed AvantGuard Mk.1 when a Mk2, based on the M113, was developed.

Overall, during the past seven years G-Nius robots operated for more than 60,000 hours providing the company with invaluable feedback. The latest platform, unveiled at Eurosatory 2014, is based on a 4x4 chassis featuring two power units, one at each end. These can be diesel or electric, enabling the vehicle to become a hybrid, hence the Hybrid Multipurpose Vehicle (HMV) name assigned by G-Nius to its latest product. The prototype was equipped with a mast-mounted optronic suite and an Elbit Systems weapon station. While the first G-Nius robots were equipped with dedicated systems, the Israeli company has now developed a platform-agnostic appliqué kit that will be described in the appropriate section.

Qinetiq: Thanks to contracts with various defence agencies, including the Socom, and with a significant company internal investment Quinetiq developed the Modular Advanced Armed Robotic System, or Maars, which is an armed version of its intelligence, surveillance, target acquisition, and reconnaissance robot. Tracked and powered by electric motors, it weighs 165 kg in combat order and speeds up to 7 km/h.

It is in fact a small combat vehicle in its own right with a turret armed with a 7.62x51 mm M240B machine gun with 450 rounds and with a quadruple 40 mm grenade launcher based on the M203. These are individually selectable and can fire lethal grenades such as high explosive, high explosive dual purpose or airburst HE, as well as less-lethal grenades such as sponge, buckshot, tear gas, smoke, star clusters or illumination. Escalation of force can start from non-lethal options, such as voice messages sent through the two-way hailer which also includes a 120 dB siren, as well as a green laser warning device capable to warn or dazzle a potential threat. The turret can rotate on 360° at a speed of 155°/s, elevation arc being –20°/+60°. A 360° view is provided by a gimbal-mounted suite that includes a x12 digital zoom 75° field-of-view day camera and a x2 digital zoom thermal 36° field-of-view 320 x 240 resolution camera. This being the equivalent of the commander's panoramic periscope on a tank, the "gunner's" sights are mounted coaxially to the machine gun and come in the form of a day camera with a x26 optical zoom and a x12 digital zoom, a 640 x 480 thermal camera with 47° FoV and x4 digital zoom ensuring sighting at night or in difficult conditions; a laser rangefinder provides target range to be fed into the fire control system.

A shotgun detection system can be added to provide cueing for the fire control system. The "pilot" can rely on front and rear 95° field-of-view day/night cameras. Operating time varies from three to twelve hours depending on the mission, an integrated sleep mode allowing to save battery power extending autonomy up to a week. The Maars can be operated with QinetiQ's Tactical

Robotic Controller, which is common to most of the company's robots, or via a Toughbook Laptop Controller. The system is always controlled by an operator, who can instantaneously shut off power through a dedicated button on the hand controller. Five Maars are currently being tested by the US Marine Corps, which is writing the Technical and Tactical Procedures based on the experience which is being acquired. In perspective QinetiQ is considering voice command to ease the operator's burden.

Northrop Grumman: Using the Camel logistic robot as a starting point, Northrop Grumman developed a weaponised platform known as Madss (Mobile Armed Dismount Support System). Thanks to its considerable payload capacity the platform is able to withstand medium calibre weapons, in this case a machine gun like the M240B 7.62x51 mounted on a remotely controlled weapon station. Alternatives such as the MK-19 40 mm automatic grenade launcher, the M2 heavy machine gun, the M249 light machine

The Mobile Armed Dismount Support System or MADSS is the weaponised version of the Camel, seen here in detail and during firing trials. (Northrop Grumman)

gun, as well as 25 and 30 mm low-recoil cannons are proposed. Less-than-lethal systems, such as the FN Herstal FN303 can also be installed.

Gate Elektronik: Among heavy robots, the Robas developed by Gate Elektronik of Turkey, has a quite peculiar architecture. It features four short tracks, each powered by an electric motor linked to a sprocket, an idler fixed to a strut providing the adequate tension for the track. What is peculiar is that a motor allows to rotate each track to change its angle of attack to provide optimal stair climbing capacities as well as obstacle overjump, the Robas being able to overcome an 800 mm obstacle.

Gate Elektronik of Turkey developed the Robas, which is fitted with four tiltable tracks to ensure good stair climbing and obstacle crossing capabilities. (Armada/Paolo Valpolini)

Batteries ensure a four-hour autonomy with a maximum range of 25 km while maximum speed is 10 km/h. Operational range from the control console is one kilometre. The robot's empty weight is 250 kg, the Robas being able to carry payloads of 150 kg; this allows to install different types of systems, such as stabilised weapon platforms, gimballed optronic sensors, land surveillance radars, mine detection kits, jammers, etc.

Oto Melara: While its small TRP3 NEC is aimed at infantry units, Oto Melara's TRP2 was designed as a heavier and more capable system to increase the ISTAR arm of the Italian Army cavalry units. However the situation in Afghanistan, with the increased risks for soldiers ensuring security to forward operating bases, has led to an urgent requirement for an armed robot to patrol such base perimeters. The TRP2 FOB (also known as TRP2 Combat) was thus developed from an existing platform that already embedded most of the necessary features such as its ability to be disassembled into in man-portable modules. It uses a tracked chassis powered by electric brushless motors, capable to reach 15 km/h, its Lithium-ion batteries ensuring a four-hour endurance. In addition to a INS/GPS fit, a first autonomous navigation module has been installed to include obstacle avoidance and thereby considerably reduce operator workload, though it becomes vital when waypoint-navigation is adopted.

To improve stair climbing capabilities, track length was increased compared to the earlier prototype, and a robust tail added. The system is operated by means of a modular control unit made of a joy-pad, a communication box and a ruggedised PC. The operator in the loop not only controls the robot movements, but more importantly

Oto Melaras TRP2 FOB armed robotic platforms are close to obtain their qualification but might miss the timing for an Afghan deployment. (Armada/Paolo Valpolini)

is responsible for firing the on-board weapons, typically a Beretta ARX160 5.56 mm assault rifle or an FN Minimi light machine gun of the same calibre, or a Beretta GLX160 single shot 40 mm grenade launcher. At the rear of the robot a mast carries the pan-tilt-zoom camera used for target acquisition as well as a fixed wide-angle camera that provides the operator with the image of the terrain ahead as well as a portion of the forward part of the robot itself. Narrow field of view sighting optronics are installed over the weapons cradle with on the left a day camera, and a DRS Technologies uncooled thermal camera on the right.

The system has been thoroughly tested at the Army range in Nettuno, and over 3,000 small calibre rounds and 100 grenades having been fired. The TRP2 FOB is equipped with a remote cocking device for the automatic weapon, which allows the robot to leave the base totally safe, the first round being chambered only when the operation area is reached. As for mobility the robot logged a considerable amount of kilometres; fording capabilities were tested, and an operational range of over one kilometre was demonstrated. Oto Melara has organised two courses to qualify 40 instructors. Eight such robots have been ordered by the Italian Army and two of them have been delivered since type qualification is pending. Preliminary technical clearance

A detailed view of the TRP2 FOB armament, consisting a 5.56 mm automatic weapon and a one-shot 40 mm grenade launcher. (Armada/Paolo Valpolini)

was expected in late July, following which one system would be delivered to operational units for testing, and a second for completion of electro-magnetic compatibility tests. Considering that the Italian contingent will soon leave Afghanistan, it looks unlikely that the TRP2 FOB will see deployment there.

The TRP2 RISTA (for Reconnaissance, Intelligence, Surveillance and Target Acquisition), also known as TRP2 Cavalry, has quite a different chassis. It features an inverted trapeze track that ensures good stair climbing capacity. Due to its peculiar reconnaissance role it can be disassembled in backpackable modules of less than 20 kg, which partly frees it from the need to be transported by a vehicle to its starting point. Maximum combat weight is around 90 kg and speed 15 km/h on flat terrain. The payload comes in the form of a Selex ES Mini Colibri that can be elevated by a pantograph arm. The Sensor suite includes an uncooled 320x240 pixel thermal camera with a 4.6° field of view, a daylight super-HAD camera with a 2.4° to a 46° field of view zoom, and an eye-safe laser rangefinder with a range of 4,000 metres. The arm can rotate ± 180° while the sensor head has an elevation arc of ± 40°. This robot will provide the close range reconnaissance capability to the Freccia Explorer, the version of the 8x8 that will

Although it retains the TRP2 designation, the TRP2 Rista has a wholly different chassis compared to the TRP2 FOB; it carries a Selex ES Mini Colibri sensor package. (Armada/Paolo Valpolini)

equip Italian Army reconnaissance units. Longer range recce duties are entrusted to the Horus, the Oto Melara drone that can be launched from a 120 mm gun barrel or from a light tube of the same calibre, as installed on the Freccia recce version.

Oto Melara is also developing the TRP2 HD for Heavy Duty – around 300 kg with a 100 kg payload capacity – with a view to replacing current explosive device disposal systems used in the Italian Armed Forces. A weaponised version of the HD model might be armed with a heavier calibre weapon, a 7.62 mm machine gun or other weapon systems. The TRP2 HD is being partially developed with Ministry for Economical Development funds as non-military versions are also envisaged.

Tecdron: In the heavy ground robots category, Tecdron of France proposes a trio of systems, the first one being the Cayman that has a quite peculiar architecture, as it features four crawler tracks, each powered by an electric motor. When folded along the vehicle chassis, made of aeronautic-grade alloy according to company tradition, the two rear tracks are along the body while the two front ones fold along the inner tracks. Two motors installed in the chassis allow to rotate the track units to allow stair climbing. The peculiar tracked solution allows optimal mobility, the Cayman being able to cope with 55° slopes and to move on 50° side slopes. Maximum speed is 6-8 km/h. Waterproof to one metre and treated against corrosion, the robot weighs 26 kg and can carry a payload of 20 kg. Extra payloads can either being integrated by Tecdron or by the customer, a plug and play interface being currently under development.

Standard sensors include a front wide-angle camera with diode lighting and a microphone; however, to improve visibility a second camera mounted on a short swivelling arm is being integrated (arm and camera are parked within the body but raise at about 350 mm from the ground in use). A data link provides a line of sight operational range of one kilometre (300 metres in urban areas). The operator uses either a mini console with a 7-inch screen or a ruggedised notebook. The Li-ion 12 volts

Tecrdon's Cayman features four swinging tracks that allow it to overcome complex obstacles, while its architecture allows to reduce considerably its size in transport configuration. (Tecdron)

When used together with its trailer Tecdron's Quator can carry a payload of 150 kg, a considerable performance for a 29 kg platform. (Tecdron)

20 A/h battery ensures three hours endurance, though a second one will double that. Numerous payloads are proposed by Tecdron, such a three-axis video turret with a x36 zoom camera, a thermographic videocamera, a laser rangefinder, gas sensors, etc. It made its public début at Eurosatory 2014, but feedback already acquired from potential users is leading to the latest development iteration.

The wheeled equivalent of the Cayman in the Tecdron portfolio is the Quator, a 29 kg 4x4 with 260 mm diameter wheels offering mobility performances that are a notch below those of its tracked stablemate, but able to cope with a 45° climb and a 40° side slope. It can climb over 200 mm high obstacles. It features the same sensors, although a second camera is installed at the rear. The battery has a larger capacity, a 24 volts 30 A/h Li-ion, yielding four hours of use. The Quator can carry a payload of up to 50 kg, and tow a four-wheel trailer with a 100 kg load. A clamp allows to hook up to the trailer with the help of the rear camera. The Quator is equipped with the same data link and can carry the same payloads as the Cayman. It is fully industrialised and the French Army is amongst its users. A track is being developed for the Quator and a robotic arm is also among systems that are in final development stage.

The champion of Tecdron's robots is the 4x4 Quator XL. Although the name is similar to that of the previous system, the XL suffix is justified by its 260 kilos and ability to carry a 500 kg load. Its prime task is to carry the loads of soldiers on foot, but it can carry recce equipment for instance. Each 390 mm diameter wheel is powered by a 1,500 W electric motor which multiplied by four provides a good pull and the ability to climb 40° slopes and cross 35° side-slopes. Vertical obstacle clearance is 300 mm while maximum speed is 15 km/h. Remote operation remains one kilometre though the Quator XL will be endowed with a self-autonomy system that is still in the evolution phase. It has the typical features of Tecdron's robots in terms of construction materials, sensors and man-machine interfaces. The Quator XL is a fully developed product, Tecrdon however testing new options for tyres to further improve mobility on specific terrains.

For very difficult terrain Tecdron proposes the Scarab LX, a 215 kg tracked system, with a 200 kg payload able to overcome 400 mm vertical obstacles. Also suitable for reconnaissance missions, this robot seems however particularly useful for bomb disposal operations and short-range inspection in hazardous areas.

Jordan Electronic Logistic Support: As its manufacturer's name implies, the tracked Lynx proposed as a multirole platform was developed in Jordan. The chassis weighs 120 kg and is powered by two electric motors. Two driving CCD colour cameras are installed, one at the front and one at the rear. Numerous payloads are proposed, including a robotic arm, disruptors, a fork-lift, a jammer, a pan-tilt-zoom camera with x26 optical and x12 digital zooms. In its bomb disposal guise the robot is known as Lynx-E/J; the Lynx-C is the combat configuration, equipped with a remotely controlled station that can be armed with an M16 rifle, a 7.62 mm machine gun or a rocket-propelled grenade launcher. The Lynx is part of Jordan's Jels soldier modernisation programme and is designed to be integrated in the system's C4I structure.

KADDB: Another Jordanian company, KADDB unveiled a new Multi-Functional Robot (MFR) at Sofex 2014 – a 6x6 with each wheel individually powered by its own motor. The front and rear wheels protrude from the chassis, which de facto allows 90° obstacles to be engaged. The MFR can drive through a 150 mm ford, cross a 450 mm-wide ditch, and reach 12 km/h (creeping speed being 2 km/h). Batteries provide two to three hours of endurance. With two

KADDB of Jordan developed a series of ground robots of different weights. Seen here is the MFR displayed at SOFEX 2014 armed with two rocket launchers. (Armada/Paolo Valpolini)

driving cameras, one in front and one at the rear, and with a two-way audio system with microphone and loudspeaker, the MFR can be fitted with numerous payloads.

At the exhibition it was shown in combat guise with a turreted system. A brochure says that range is 800 metres although company officials talked about two kilometres. The turret was fitted with an optronic sighting camera that provides the operator with a size-comparison distance measurement

To improve the security of its Strategic Missile Forces, Russia developed an armed tracked robotic platform known as MRK-002-BG-57 armed with a heavy machine gun

system, shapes of a man, a small vehicle, a big vehicle and a building being available to estimate distance, thus avoiding the need of a laser rangefinder. The turret was armed with two RPG-32 Hashim rocket launchers, a Russia and Jordan co-development. Firing is piezoelectric and ensures 200 firings. A 7.62 mm machine gun can be added. The MFR was very much at a prototype stage. It is unclear if this new ground robot replaces the robot that has been shown in the past.

Russian Army: Russia has recently unveiled an armed robot that is being deployed by the Strategic Missile Forces to increase security of those assets. Known as the MRK-002-BG-57 it is based on a tracked vehicle, the whole system weighing some 1,100 kg. With no particular company identified as its developer, it is apparently powered by a hybrid system with a 250 km range, a maximum speed of 35 km/hour and a ten-hour endurance. The powerpack is located at the back, and stabilised remotely controlled weapon station is mounted in the centre of the vehicle.

According to Russian sources the robot is able to aim, track and hit targets both in automatic and semi-automatic modes. The turret is equipped with a day camera, a thermal camera, a laser rangefinder and a ballistic computer, a radar sensor being available for long-range surveillance. Driving cameras are also installed on the chassis. Different types of weapons can be installed, a Kalashnikov 7.62x39 mm assault rifle with 500 rounds, or a 12.7 mm machine gun with 30 rounds, or a 30 mm automatic grenade launcher, either an AG-17A or an AG-30. The data link has a line of sight range of five kilometres.

Robots At the Wheel!

Electronically controlled automatic gearboxes, electronically actuated throttles, plus electrically controlled power steering systems that are now increasingly a standard fit on modern vehicles come as a real gift from the sky to robotics developers. Indeed command signals can now more easily be injected directly into those vehicles' existing processing units meaning that the cumbersome actuators hitherto required can gradually be sent to the breakers.

The roller-equipped M-ATV demonstrated by Oshkosh at Eurosatory 2014 is equipped with the company Terramax robotic suite, the sensors of which are visible in the lower right corner of the picture. (Armada/Paolo Valpolini)

The extra advantage of such systems is that not only are they transferable from one vehicle to another, they will eventually be so cheap that the "control injection" system per se will be able to remain in place and simply be switched off to restore the conventional use of the vehicle.

Oshkosh: If an American manufacturer of large vehicles were to be tagged as one of the leaders in the field of heavy robotised vehicles that would definitely be Oshkosh Defense. It started developing the TerraMax robotic technology in the early 2000 under a Darpa solicitation. Following years of development and refining, in August 2012 the US Marine Corps Warfighting Lab and Oshkosh Defense applied the TerraMax technology to test a convoy that included five normal and two uninhabited vehicles. The latter travelled in full autonomous mode albeit under the monitoring of an operator equipped with a remote-control unit. While the company remains committed to the US Office of Naval Research Cargo UGV project, which seeks to bring robotic capabilities to logistics convoy missions to help reduce troops' exposure to

A close-up view on the all-so-important roof mounted sensors of the Terramax to provide the system with a clear view of what is lying ahead of "him", but which makes one wonder why the windscreen needs to be kept so clean! (Armada/Paolo Valpolini)

threats, Oshkosh is also looking at other applications for its TerraMax, which is constantly being upgraded.

At AUVSI 2014 and Eurosatory 2014 Oshkosh exhibited a company M-ATV equipped with a Humanistic Robotics route clearance roller capable to work in full autonomy. Vehicle dynamics were adapted to the roller, and Oshkosh will carry on experimentations for the next couple of years on route clearance operations. The demonstrator shown in Paris was equipped with a roof-mounted lidar. This is regarded as a prime sensor and is particularly efficient in dust conditions, assisting the radars installed at each corner of the vehicle, while electro-optic sensors are used to allow the operator to have a clear view of the situation. The upgrades consisted mostly in the adoption of a new and faster computer able to cope with a higher sensor resolutions required for increased perception of the vehicle's surroundings, which includes detecting obstacles in dust or vegetation and in turn allow the vehicle to move faster (exactly like a motorist is able to drive faster at night if given more powerful headlights). The new kit features an open architecture, improving the TerraMax's ability to accept new types of sensors.

Lockheed Martin: Fort Hood, Texas, 14 January 2014: a convoy made of four vehicles, two Palletized Loading System prime movers, an M915 tractor trailer truck, and a Humvee gun escort vehicle cross the "fake town" negotiating all manner of obstacles including local traffic, pedestrians and so forth. What made the event exceptional was that, with the exception of the Humvee, all convoy vehicles were unmanned – literally. They were equipped with the Autonomous Mobility Appliqué System (Amas) developed by Lockheed Martin following a contract received in October 2012. The aim was to develop a multi-platform kit integrating low-cost sensors and control systems that could be installed on US Army and Marine Corps vehicles, reducing driver's workload or providing full automated driving under supervision. The vehicle maintains the capacity to be manually driven but adds sensors and control functions that alert the driver when a danger occurs. According to US military statistics, most accidents in convoys are caused by fatigue and loss of concentration. The Amas is part of the Convoy Active Safety Technology (Cast) programme, for which Lockheed Martin experience acquired with the SMSS robot was put to good use. Key sensors remain the GPS, the lidar and the radar, together with the control system that provides artificial intelligence and decision-making capabilities. A second series of demonstrations tests were completed in June 2014 at the Department of Energy's Savannah River Site in South Carolina.

These involved a completely unmanned leader vehicle followed by a convoy of up to six additional fully autonomous followers operating at speeds of up to 65 km/h, all equipped with the Amas (the test also doubled the length of the convoys). All vehicles were medium and heavy trucks and consisted of one FMTV, one MTVR, two PLS, two M915 tractors and one HET. At time of writing further safety tests were scheduled for July 2014 followed by an operational demonstration in the July-August 2014 timeframe.

The Autonomous Mobility Appliqué System was developed by Lockheed Martin as part of the Convoy Active Safety Technology programme. (Lockheed Martin)

Mira: In Britain Mira is specialised in advanced vehicle and systems technologies, with robotics being amongst them. The company has developed the Mace (Mira Autonomous Control Equipment), a platform-agnostic suite that can be integrated virtually on any ground platform to provide a modular level of autonomy, remote, semi-autonomous or fully-autonomous, depending on customers' needs. The Mace has been integrated into different vehicles to show the systems' potential applications (Sherpa and Land Rover based solutions focused on logistic support for dismounted infantry, while a Guardsman- equipped vehicle acted as a safety perimeter awareness 4x4 platform).

Mace is a platform-agnostic robotic suite developed by Mira and deployed in Afghanistan on unmanned roadside bomb detection Land Rovers. (Mira)

The one system currently in use is the one known as "Project Panama" which acts as an unmanned route-proving and clearing system. In service since 2011 in Afghanistan, the system is used for bomb detection and is based on a Snatch Land Rover (SN2). The Panama vehicle is used both in tele-operated and autonomous modes, at a range of up to 20 km to maximise personnel safety. In mid-June 2014 the British Army announced that the Panama will be retained in service until 2030, with Mira ensuring further development of its MACE technology platform. At AUVSI Mira illustrated its road edge detection capabilities highlighting the use of vision detection following years of use of lidars and radars. This is not only due to cost considerations – a vision detection system costing an order of magnitude less

than a lidar – but also because such further types of sensors can be used to feed additional data into the system and thereby improve reliability and accuracy.

Ruag: In Switzerland Ruag Defence is also working on a kit that transforms existing vehicles into supervised autonomy vehicles. Known as the Vero (Vehicle Robotics) it was first shown in fall 2012 installed on board a GDELS Eagle 4 light armoured vehicle. Demonstrated at Eurosatory 2014 in remote-controlled mode, the system is also capable of following a pre-planned route designed with successive waypoints. Compared to the vehicle seen in 2012, which worked only in tele-operated mode, the one seen in Paris has a suite of obstacle avoidance sensors at the front: two lidars are located on the right and left sides of the bumper (but will eventually be moved on the bonnet to reduce dust disturbances), and a radar is installed in the centre of the bumper with what was termed "a special optic sensor" on its right.

According to Ruag Defence a few more months of testing are needed to qualify both software and hardware. The Vero is currently being integrated on two more military vehicles, the model of which was not unveiled, while in 2015 it will be installed on a pure robotic vehicle with a mass of around three tonnes, though the choice between tracks and wheels has not yet been made. Ruag is in discussion with partners and has still to decide if it will install its Vero on an existing platform or on a purposely developed one.

The Torc Robotics Ground Unmanned Support Surrogate was developed on a Polaris MVRS700 6x6 chassis. (Torc Robotics)

Torc Robotics: A specialist in robotic solutions in the military, mining, agricultural and engineering worlds, this American company is now working on the US Marine Corps Ground Unmanned Support Surrogate (Guss) programme. Torc Robotics has been involved since 2010 in the development of a light vehicle capable to autonomously resupply troops in combat, carry the load of a Marines team or perform casualty evacuation. Using its robotics modules, Torc Robotics transformed four Polaris MVRS700 6x6s into robotised vehicles able to carry a payload of around 900 kg.

The AutoNav module is the key element that allows to robotise the vehicle allowing three different modes of operation: waypoint navigation, follow-me and tele-operation. The interface is the WaySight, a handheld unit that allows the operator to choose the mode of operation and control or supervise the vehicle. The technology was then improved and migrated onto an M1161 Growler, the vehicle selected by the US Marine Corps to fit inside the V-22 Osprey – the programme being known as Guss AITV (Autonomous Internally Transportable vehicle). The sensor suite includes an inertial navigation system, cameras and lidar. It has been put to test for the first time in a real exercise during Rimpac 2014 in Hawaii last June, showing its usefulness in speeding up casevac operations and by lightening the Marines burden. The need of some technological improvements has been identified. The company appliqué system has also been used to develop the Robotic Assault Zone Terminal Evaluation Kit able to perform the environmental assessment of potential air assault landing strips to reducing risks to Special Tactics Surveyor Teams. It draws on many of the technologies developed for the Guss and is based on a Polaris LTATV equipped with a Mosquito soil sampling device from MDA.

Polaris vehicles have been recently

Ruag of Switzerland is working on its Vero programme that currently uses a GDELS Eagle 4 (top). Part of the sensors are roof-mounted (bottom, left) while others are mounted on the bumper. (Armada/Paolo Valpolini)

Torc Robotics exploited the experience acquired with the Guss programme to robotise the Osprey-transportable US Marine Corps M1161. The resultant Guss AITV was demonstrated at the Rimpac 2014 exercise. (Torc Robotics)

Polaris Defense increasingly thinks "robotisation" when designing its vehicles. Its Ranger XP 900 EPS was selected by Darpa to take part in a robotics challenge simulating a disaster relief operation. (Polaris Defense)

selected by the Darpa to participate in a Robotics Challenge simulating disaster relief scenarios. Polaris Ranger XP 900 EPS vehicles were built to accommodate robot drivers and provide mobility at the mock disaster site and customised with a remote SafeStop Electronic Throttle Kill and Brake Actuation technology. A 453-kg capacity bed provided space for the robot's power supply, and inside the cab the bench seat and tilt steering provide ample room for robots to operate the vehicle.

Kairos Autonomi: Why not replace the driver with a mechanical structure mimicking the human structure? Kairos Autonomi engineers followed that path giving birth to Pronto4 Uomo, a robotic appliqué kit that can be installed in an unmodified vehicle in about ten minutes to provide tele-operation and GPS path-following control. Unveiled in 2013, the system weighs only 25 kg and is contained in a briefcase. The structure is made of metal and mimics the human behaviour, with two "feet" activating the brake and throttle pedals, while an arm on universal joints controls the steering unit. The system can be powered by a standard BA5590 military battery, and by not requiring power from the vehicle itself reduces installation time.

Selex ES has now frozen the configuration, the final prototype being expected for Fall 2014. The current Acme,

Kairos Pronto4 Uomo definitely is the appliqué system that mostly resembles a human being, which allows it to be installed in a matter of minutes at the wheel of an unmodified vehicle. (Kairos Autonomi)

which is fully military export licence-free (Itar), should be ready for production in early 2015, Selex ES being already in talks with numerous potential customers. The driving interface is installable in 30 minutes to one hour. The carbon fibre version of the steering system weighs seven kilos as opposed to 12 kg for the steel counterpart. The 28Nm torque stepping motor rotates from 18 to 180 rpm. Navigation sensors includes a QinetiQ Canada jam-proof GPS with two antennae working on seven bands (the Acme is Galileo- and Glonass-compatible) as well as a solid-state inertial measurement unit with a 0.5% drift per hour (the latter for use when the GPS signal is lost, usually for a short time). A roof-mounted laser scanner provides collision avoidance. Tipping the scales at 60 kilos, the system offers an automatic mode maximum speed of 40 km/h and in tele-operated mode the company advises not to exceed 100 km/h. It should be noted though that the Acme must always remain under the supervision of an operator. It is capable of repeating a predetermined path with a two-centimetre accuracy, this within a speed variation of under 0.5 km/h. The throttle stepping motor provides a 14 kg force with a velocity of 300 mm/s. A pneumatic system is used both for clutch and brake actuators, generating a 60 kg force with a 300 mm/sec velocity. New geo-referenced maps can be used. A ruggedised joy-pad has been readied since Selex ES has decided to move to a game-type control system that would be more familiar with young soldiers. Selex ES is currently working on image stitching software to provide all-round vision, which will eventually feed a 3-D helmet for remote driving, possibly by late 2015.

Oto Melara: Also from Italy, Oto Melara proposes an appliqué system that was originally developed for civil purposes. The remote-control kit includes a number of actuators able to move the steering wheel, the pedals and other controls. The system can be installed and removed in about one hour, but Oto Melara is now working on new capabilities to answer the "intelligent convoy" requirement.

G-Nius: In addition to the robotic vehicles examined earlier, G-Nius of Israel has developed a new robotic suite that allows to transform any ground platform into an uninhabited device, with obvious mechanical variations to suit individual vehicle designs. While the previous G-Nius installation was made of numerous black

Selex ES Automated Computerised Mobility Equipment has been recently upgraded with new sensors, the company being also busy in developing new man-machine interfaces. (Armada/Paolo Valpolini)

Drawing on considerable experience acquired with, notably, the Guardium series, G-Nius of Israel has developed a robotic suite that allows to transform any ground platform into an unmanned system, the "brain" of which is seen here. (G-Nius)

boxes, the new product fits into a single box that contains the mission computer, the navigation unit, the video-audio system, and the power distribution unit.

The Kairos Autonomi catalogue also contains a more traditional appliqué system, the Pronto 4, a modular system that can robotise a normal vehicle with a degree of automation that ranges between tele-operation and semi-autonomy. Its installation requires less than four hours, the Pronto 4 being a series of modules, among which the brain is the computer module, while steering ring, actuators for brake, throttle and transmission allow to interface the system with the vehicle. The system is available in various configurations, the overall weight being around 10 kg.

Selex ES: This company has called on Milan-based Hi-Tec for assistance in its effort to reduce risk-exposed patrol personnel by robotising fleet vehicles (whenever possible) and particularly the lesser armoured, and thereby, the cheaper ones. In the resultant Acme (with Automated Computerised Mobility Equipment replacing the original Greek word for "highest point") Hi-Tec provides actuators, navigation systems, processing and software while Selex supplies narrow-field and 360° infrared and day vision systems, infrared lighting, systems analysis of sensory data and simulators.

Standard sensors include a day-and-night thermal uncooled camera, rear and side cameras, and a communication system; an obstacle avoidance system can be added. The system allows four different modes of autonomous operations. Line-of-sight operation range is of 20 km, but satcom can be used for longer ranges. The robotic suite is payload-agnostic, thus all sorts of payloads, from reconnaissance and jammers to weapons, can be linked to the system. G-Nius is proposing its suite for numerous types of platforms, from light wheeled vehicles to tracked infantry fighting vehicles.

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ON THE COVER: Contrary to its sea-going and airborne counterparts, the land robot has to fight its way around many more obstacles that may get across its paths. Ironically, the smaller robots can be thrown around, like this Nexter Nerva LG. The larger ones still have to turn around a tree, but might one day be able to zap it out of their way.

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